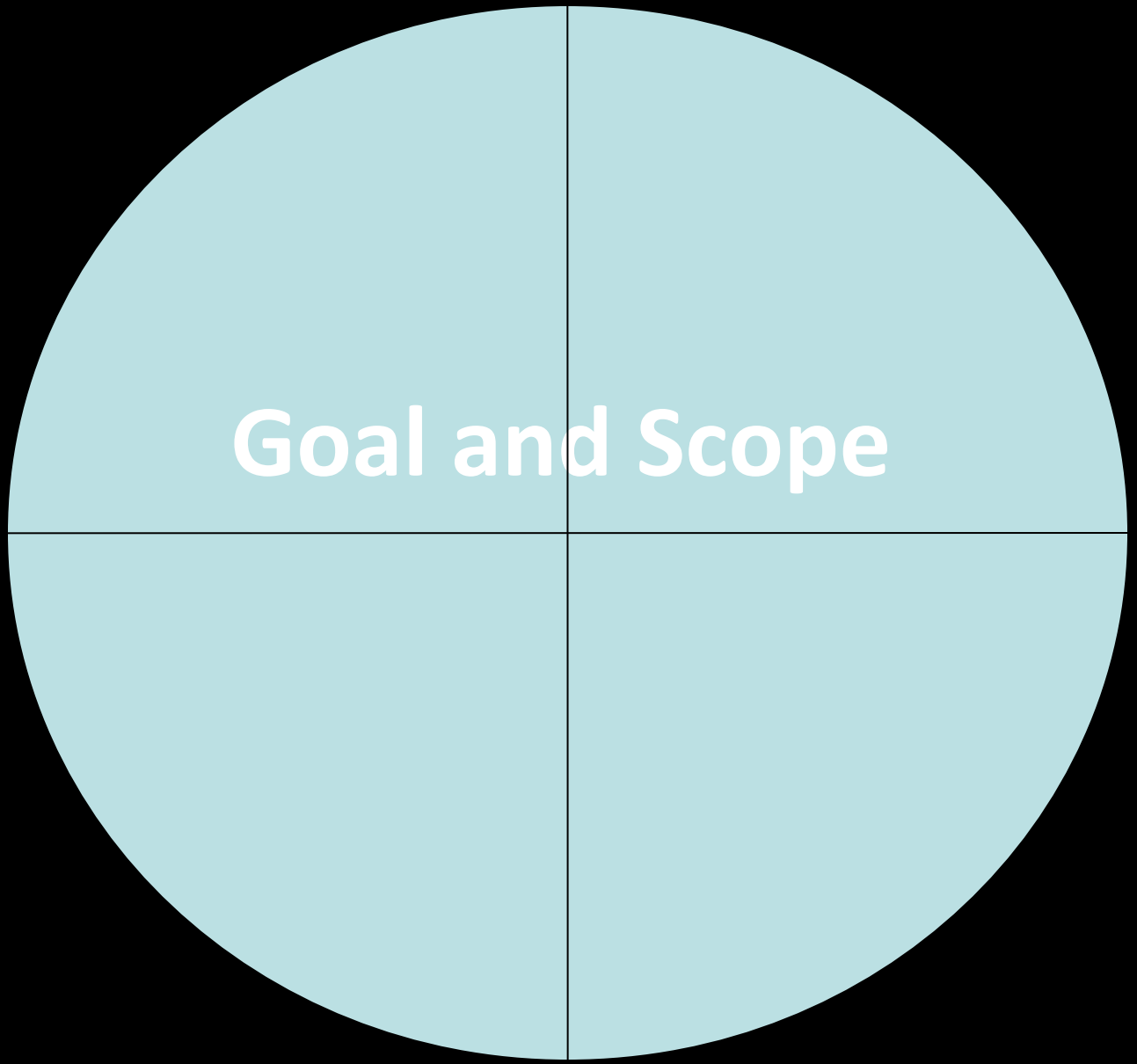
CIVL 498
LCA of UBC Buildings

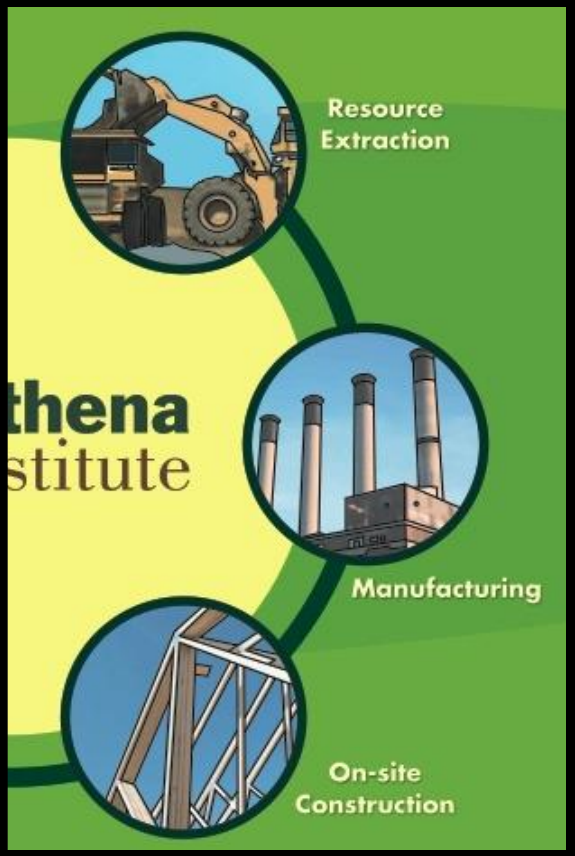
Final Presentation Outline

- Goal & Scope
- The Work
  - OnScreen TakeOff
  - Impact Estimator
  - Methods
- Results
  - Initial Results
  - Influencing Factors
  - Functional Units
  - Sensitivity Analysis
  - Energy Analysis
- Recommendations


Goal and Scope

Scope

- Physical
  - Structural
  - Envelope
  - Operating energy
- Life Cycle Stages
  - “cradle to gate”



Outputs

- Create a materials inventory for each building or complex
  - OnCenter's (Jess)

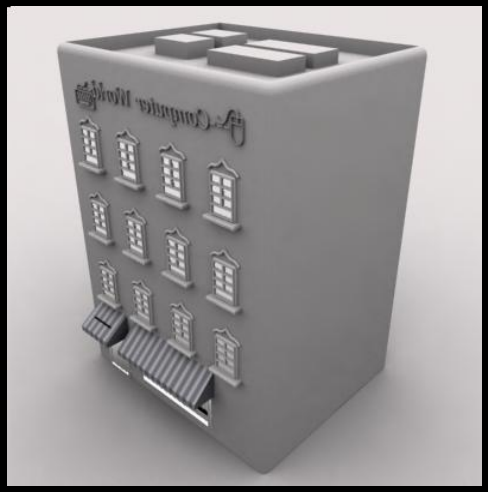
- Estimate environmental impacts
  - Athena Sustainable Materials Institute's (Ivan)

- Methods (Jack)

Functional Unit

- Per square foot finished floor area

Academic



Residence

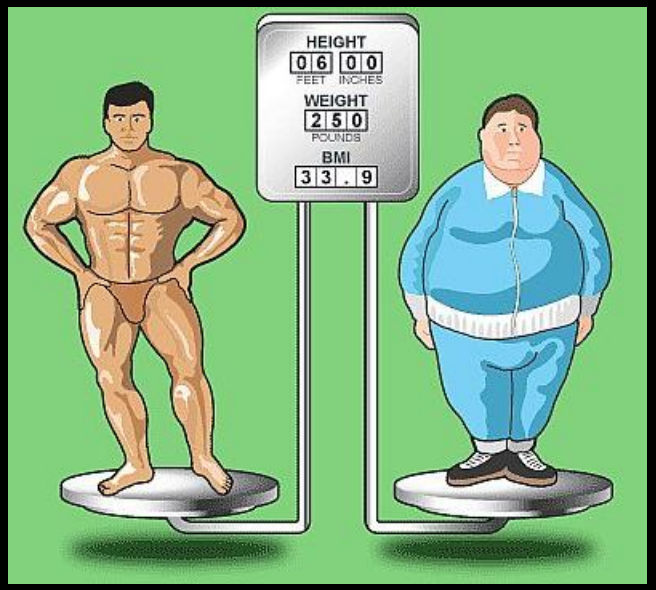
Impact Assessment

- Used Tool for the Reduction of Chemical and other environmental Impacts (TRACI) (Tyler)
  - Non-regionalized version

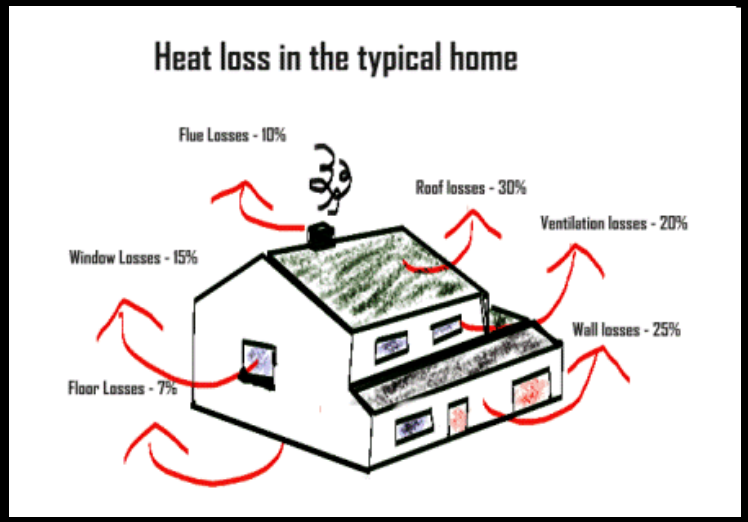
Summary Measures Included

- **Global warming potential**
- **Acidification potential**
- **Eutrophication potential**
- **Ozone depletion potential**
- **Photochemical smog potential**
- **Human health respiratory effects potential**
- **Weighted raw resource use**
- **Primary energy consumption**

Further Analysis



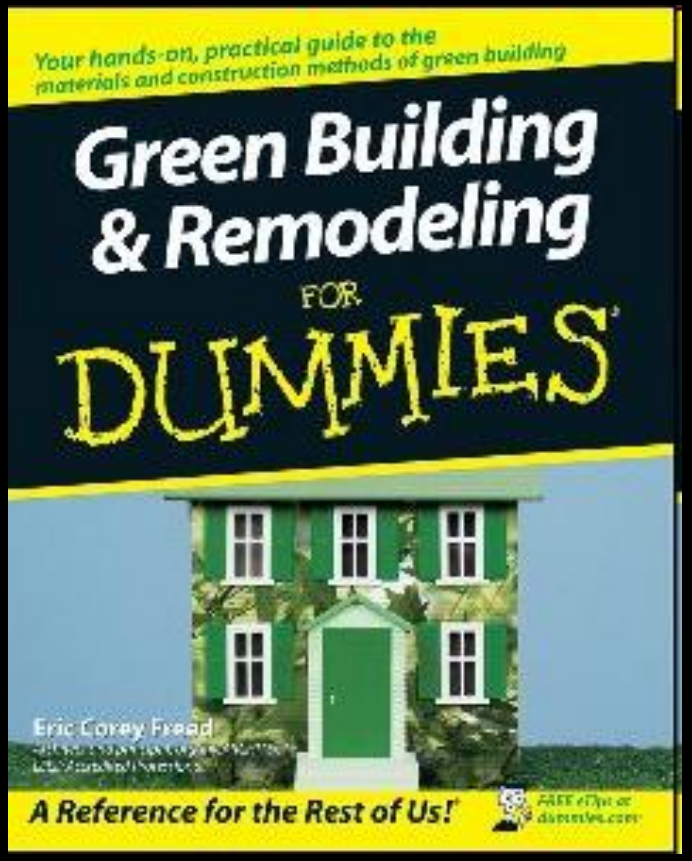
- Sensitivity (Ross)
  - Change in material volume
- Energy Modeling (Robyn)



Outcome

- Generate baseline data on estimated environmental impacts

- Use baseline as a reference for future performance upgrades



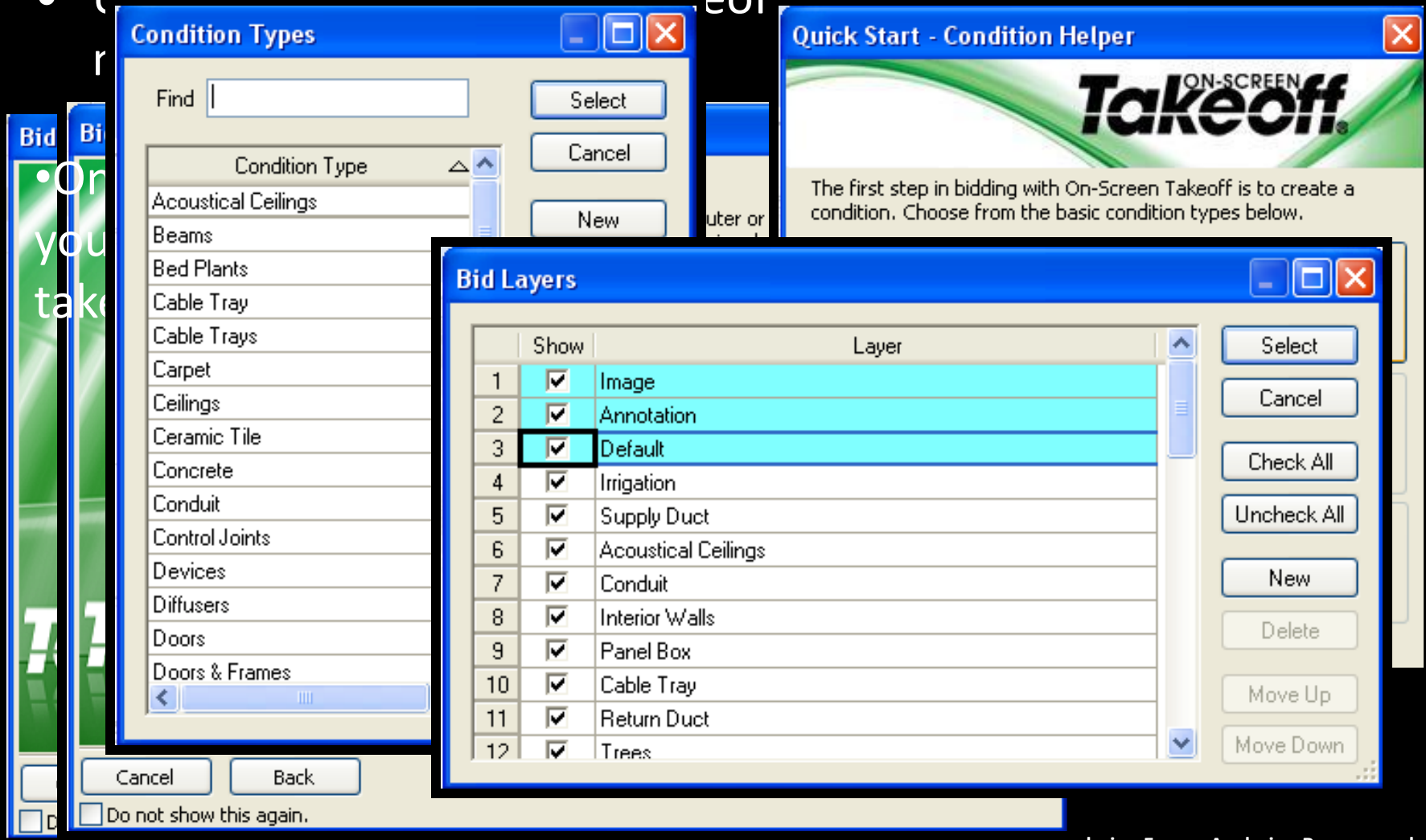
Intended Audience

- UBC Policy Makers
  - Use study to help create effective policies and frameworks
- Others Interested in LCA
  - Developers
  - Architects
  - Engineers
  - Municipalities
  - Institutions
    - Use study as a model for how to conduct an LCA

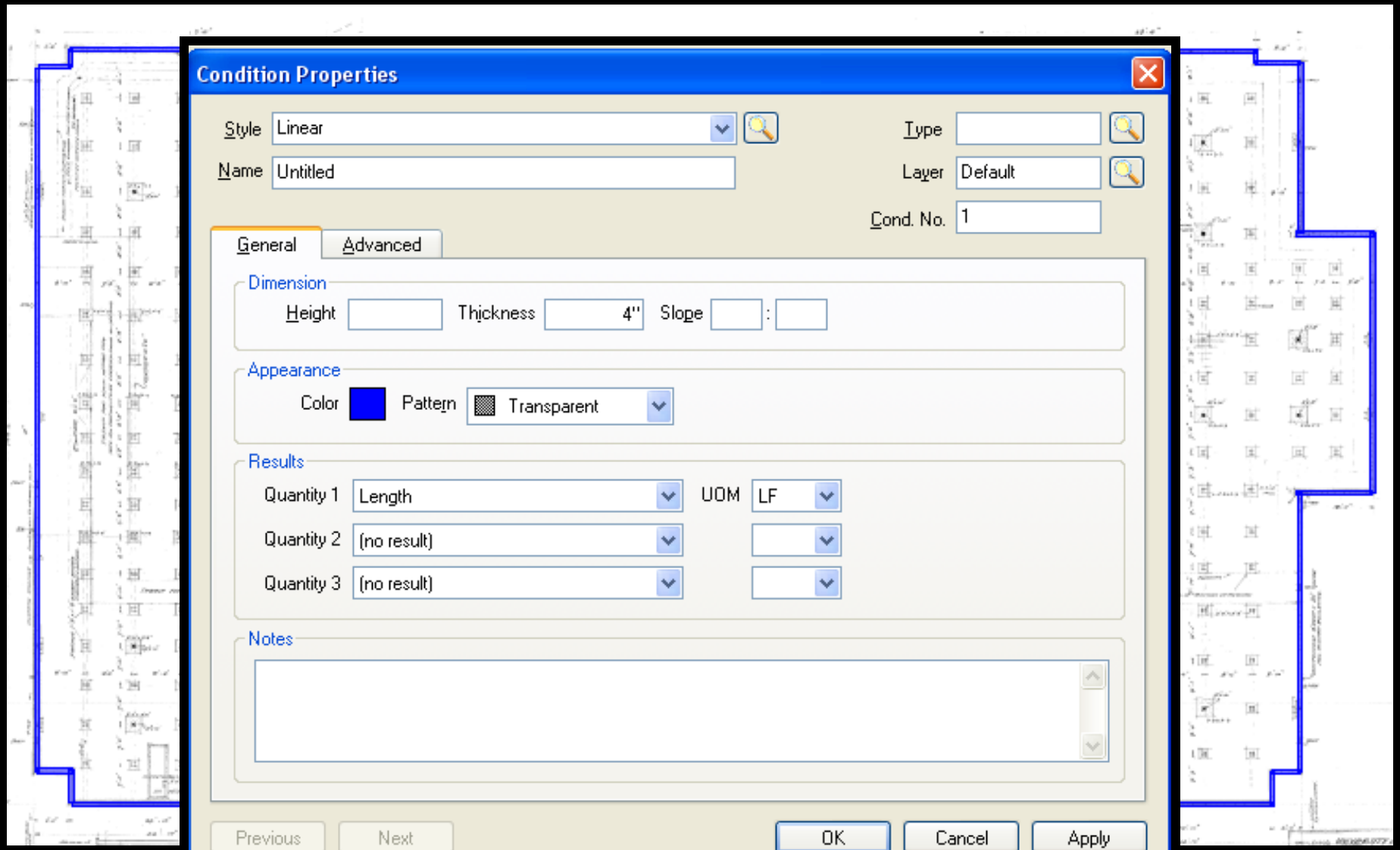

And now for some explaining!!

On Center's On-Screen Takeoff Pro

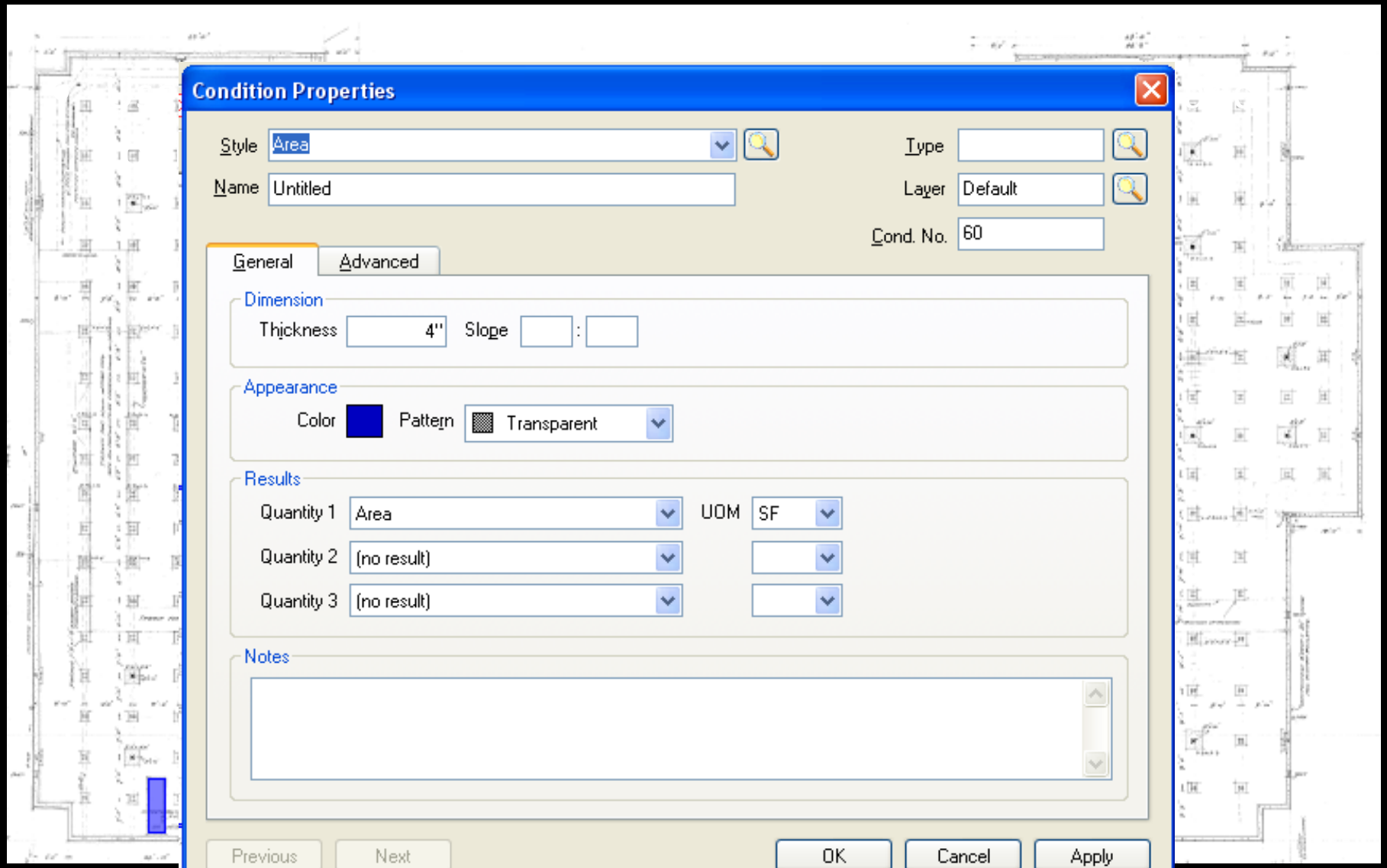
- Used to perform material takeoffs in an efficient and accurate r



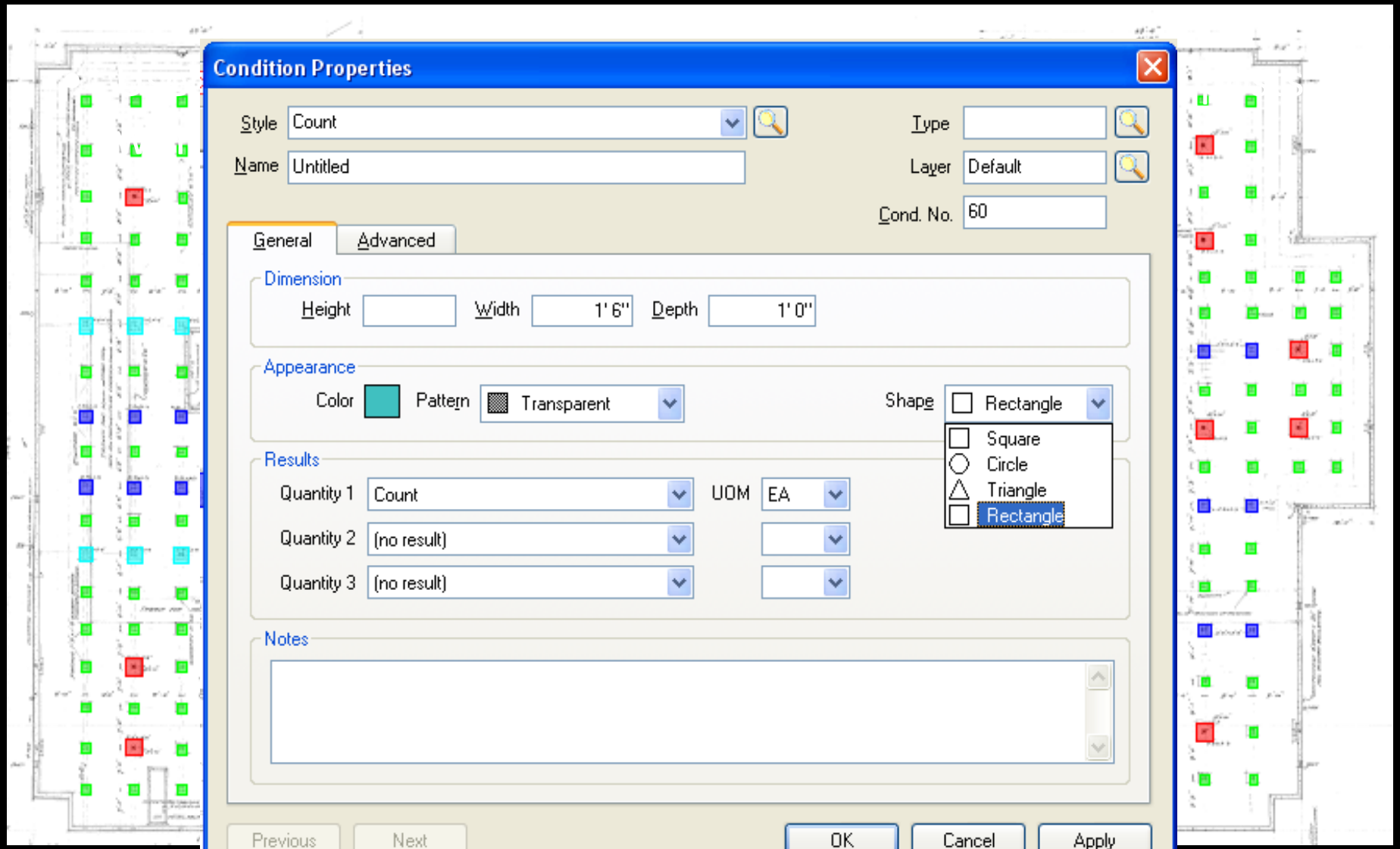
Linear Conditions



Area Conditions

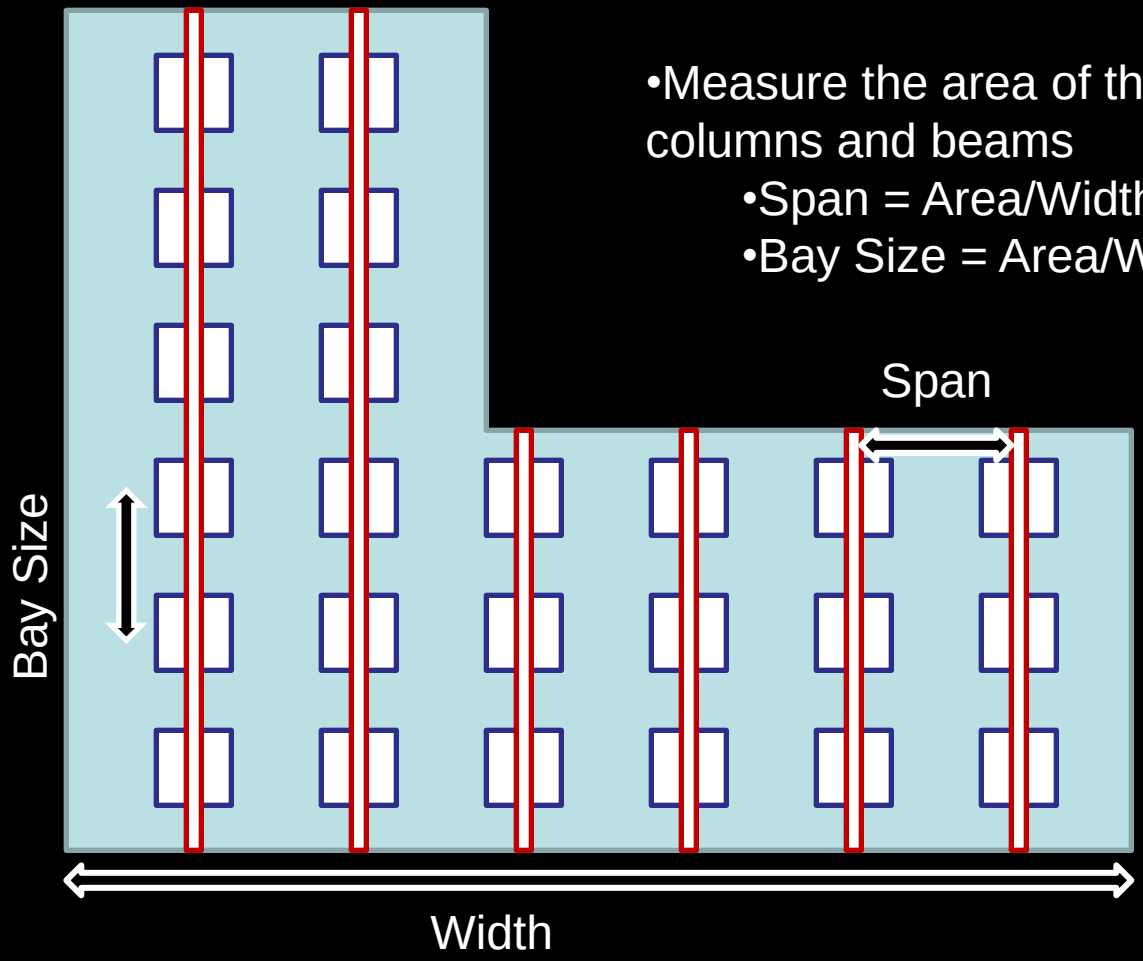


Count Conditions



Methods for Columns and Beams

- Used area and count conditions for odd-shaped floor areas

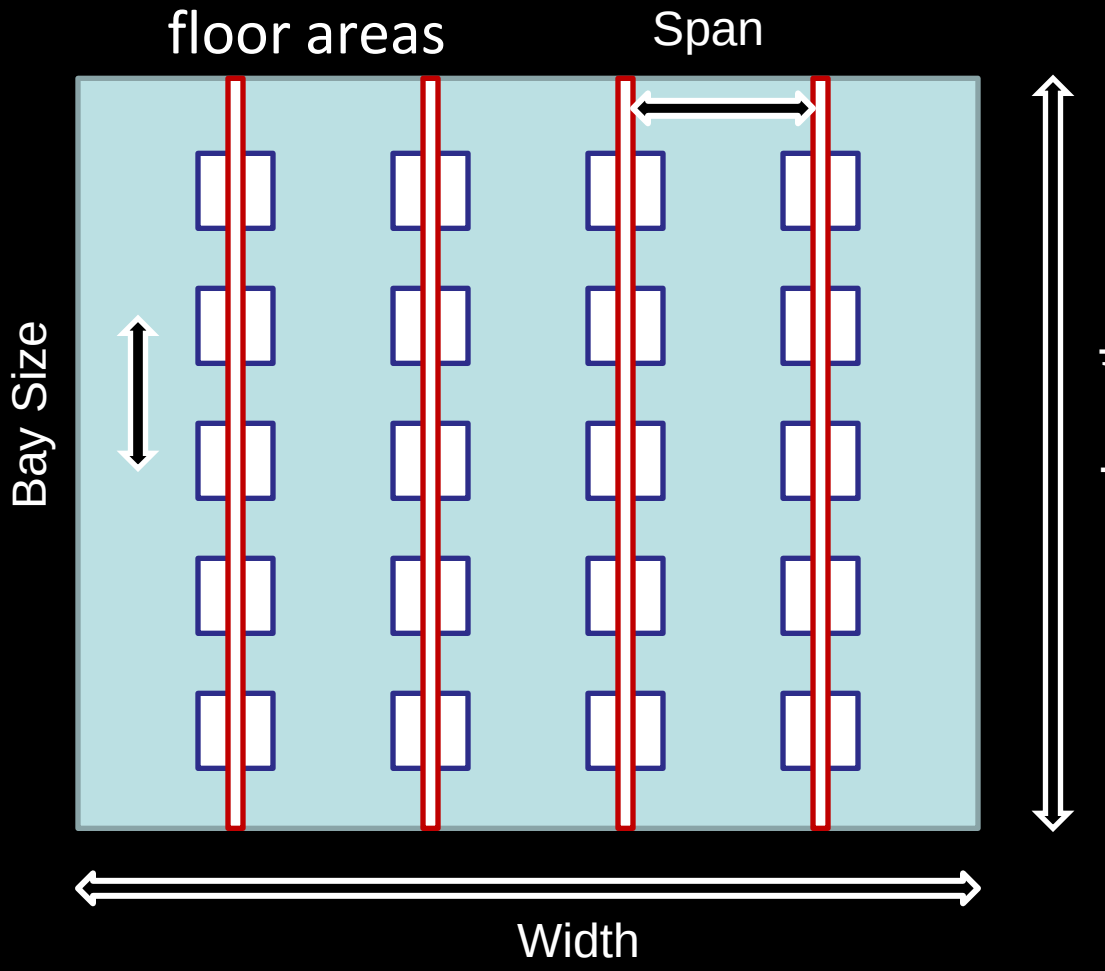


•Measure the area of the floor and count the columns and beams

- •Span = Area/Width/#of beam rows
- •Bay Size = Area/Width/# of columns

Methods for Columns and Beams

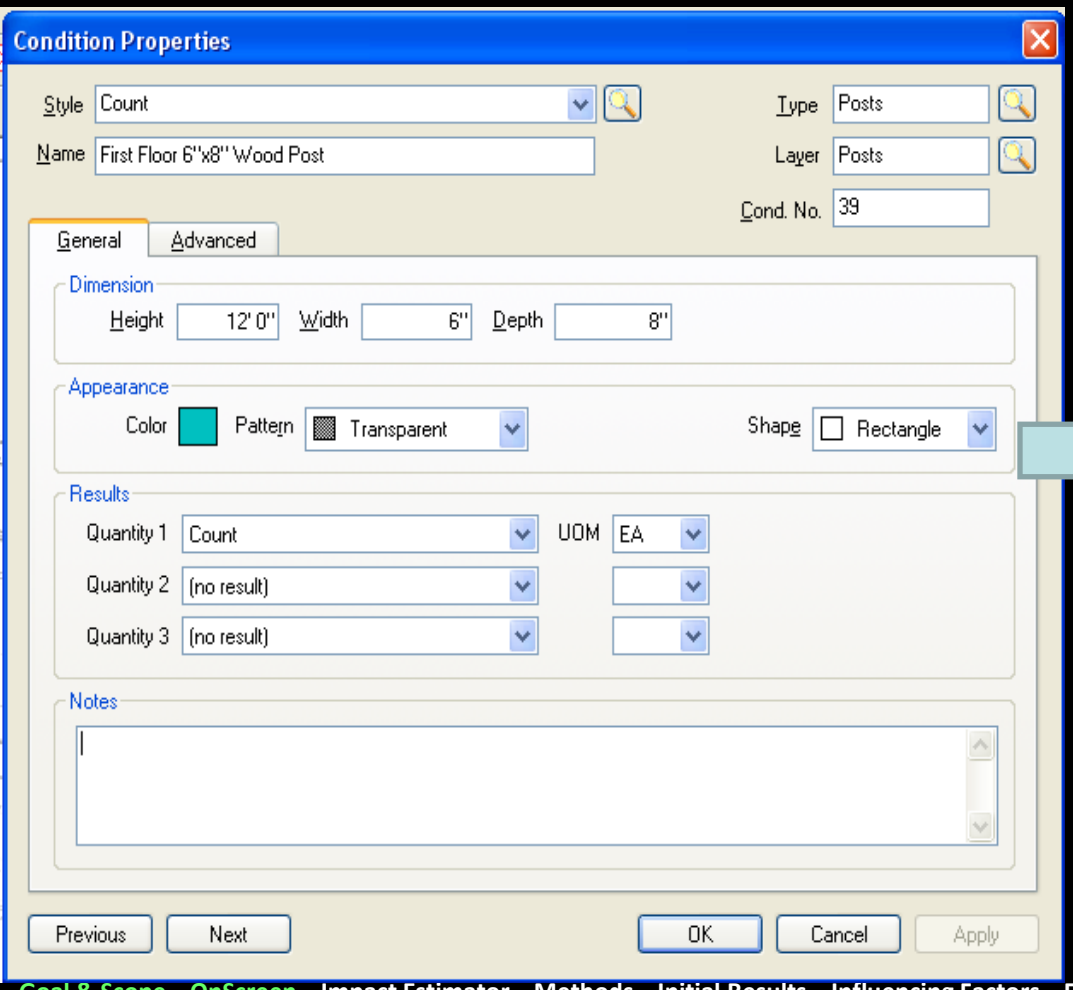
- Used linear and count conditions for square and rectangular floor areas

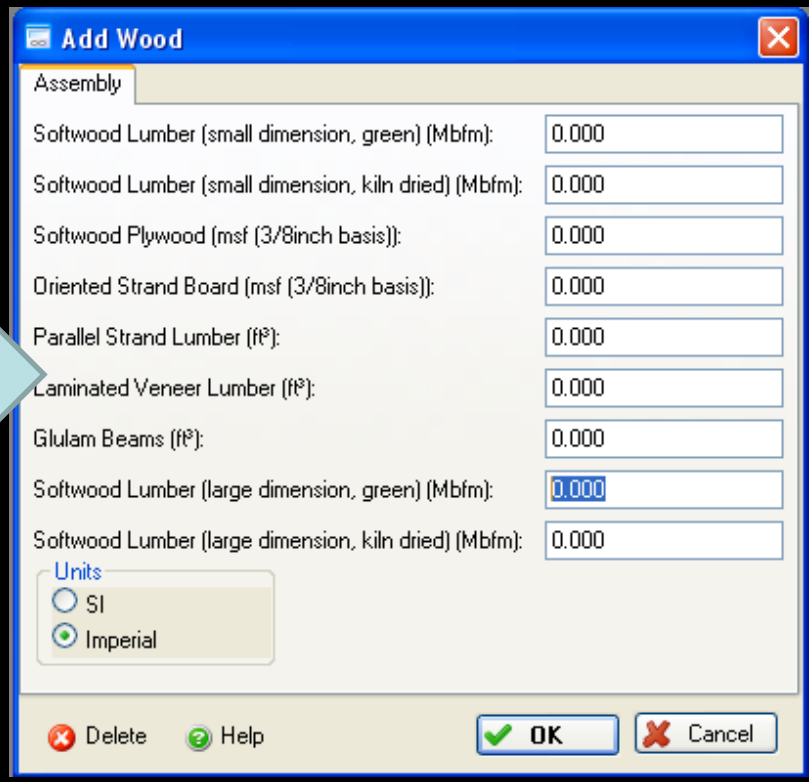


- Measure the length and width of the floor area, and count the columns and beams
  - Span = Width/# of beam rows
  - Bay Size = Length/# of columns

Methods for Columns and Beams

- Used the count condition for other floor areas





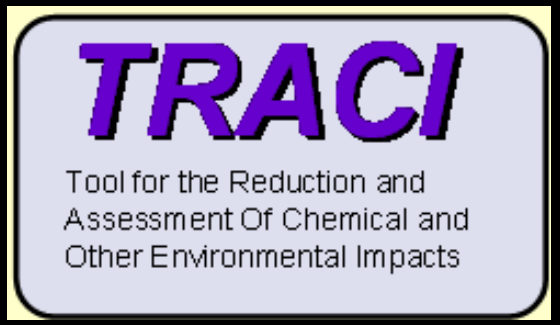
Inputs into the Impact Estimator

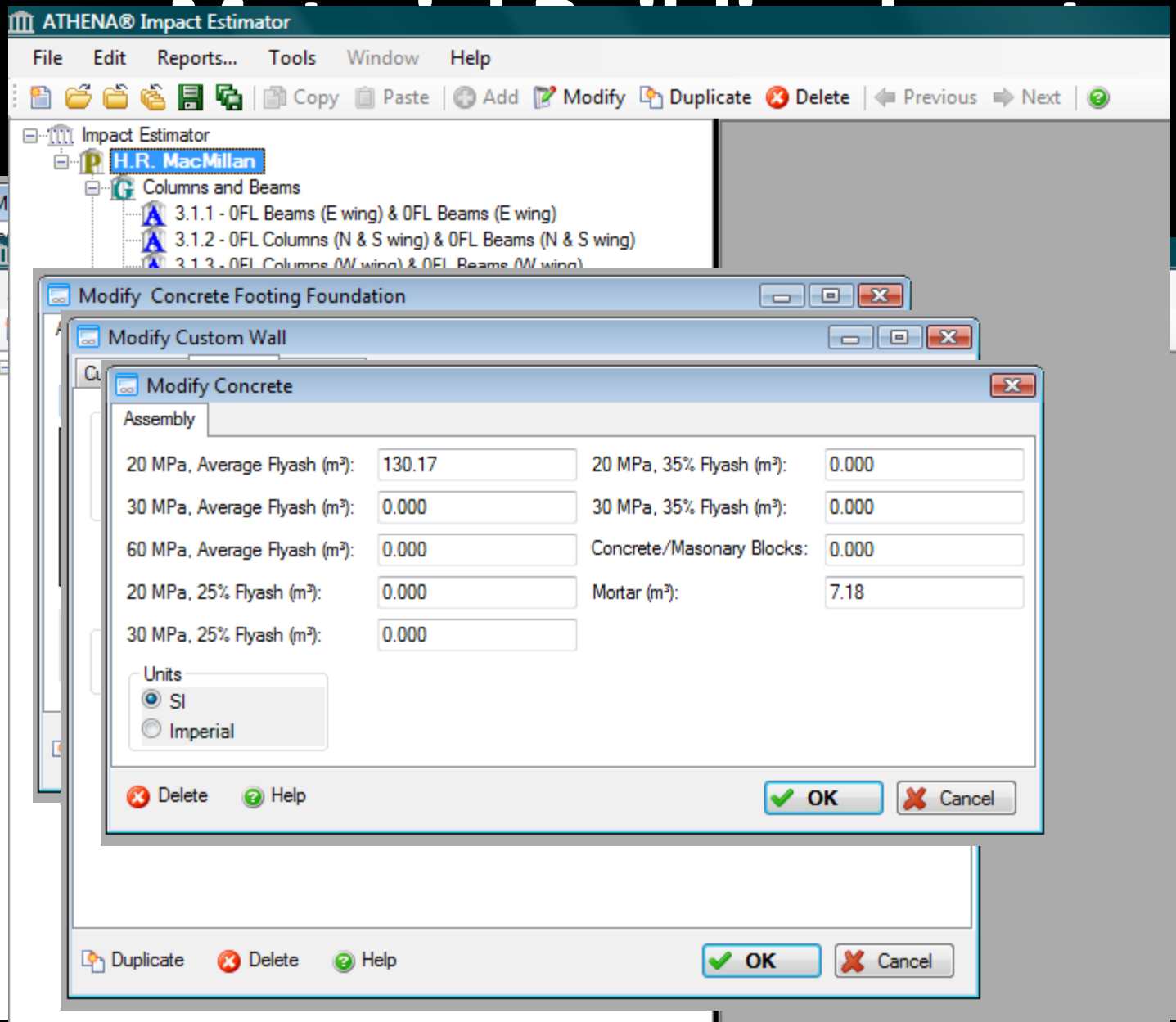
Assembly Group	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/Measured	EIE Inputs
1 Foundation					
2 Custom Wall					
	2.1 Cast-in-Place				
	2.2 Wood Stud				
		2.2.1 - Ground Exterior Wall			
			Wall Type	Exterior	Exterior
			Length (ft)	1096.000	274.000
			Height (ft)	13.500	13.500
			Sheathing	None	None
			Stud thickness	2 x 6	2 x 6
			Stud Spacing	16 o.c.	16 o.c.
			Stud Type	Kiln dried	Kiln dried
			Window Opening — Number of Windows	332.000	83.000
			Window Opening — Total Window Area (ft2)	3229.722	807.431
			Window Opening — Frame Type	Wood	Wood
			Window Opening — Glazing Type	-	Standard Glazing
			Door Opening — Number of Doors	10.000	10.000
			Door Opening — Door Type	-	Solid Wood
			Envelope — Category	-	Gypsum board
			Envelope — Material	Lath and Plaster	Gysum Regular 1/2"
			Envelope — Thickness	-	-
			Envelope — Category	Cladding	Cladding
			Envelope — Material	Lath and Stucco	Stucco - Over porous sruface
			Envelope — Thickness	-	-
			Envelope — Category	Cladding	Cladding
			Envelope — Material	Shiplap	Wood Shiplap Siding - Cedar
			Envelope — Thickness	-	-

Goa ...ions

Athena Impact Estimator

- Material building inputs
- Generates bill of materials
- Outputs Athena LCI profile
- Applies TRACI v2.2 characterization factors




ATHENA® Impact Estimator
File Edit Reports... Tools Window Help
Copy Paste Add Modify Duplicate Delete Previous Next
Impact Estimator
H.R. MacMillan
Columns and Beams
3.1.1 - 0FL Beams (E wing) & 0FL Beams (E wing)
3.1.2 - 0FL Columns (N & S wing) & 0FL Beams (N & S wing)
Modify Concrete Footing Foundation
Modify Custom Wall
Modify Concrete
Assembly
20 MPa, Average Flyash (m³): 130.17
30 MPa, Average Flyash (m³): 0.000
60 MPa, Average Flyash (m³): 0.000
20 MPa, 25% Flyash (m³): 0.000
30 MPa, 25% Flyash (m³): 0.000
20 MPa, 35% Flyash (m³): 0.000
30 MPa, 35% Flyash (m³): 0.000
Concrete/Masonary Blocks: 0.000
Mortar (m³): 7.18
Units
SI
Imperial
Delete Help OK Cancel
Duplicate Delete Help OK Cancel

blies

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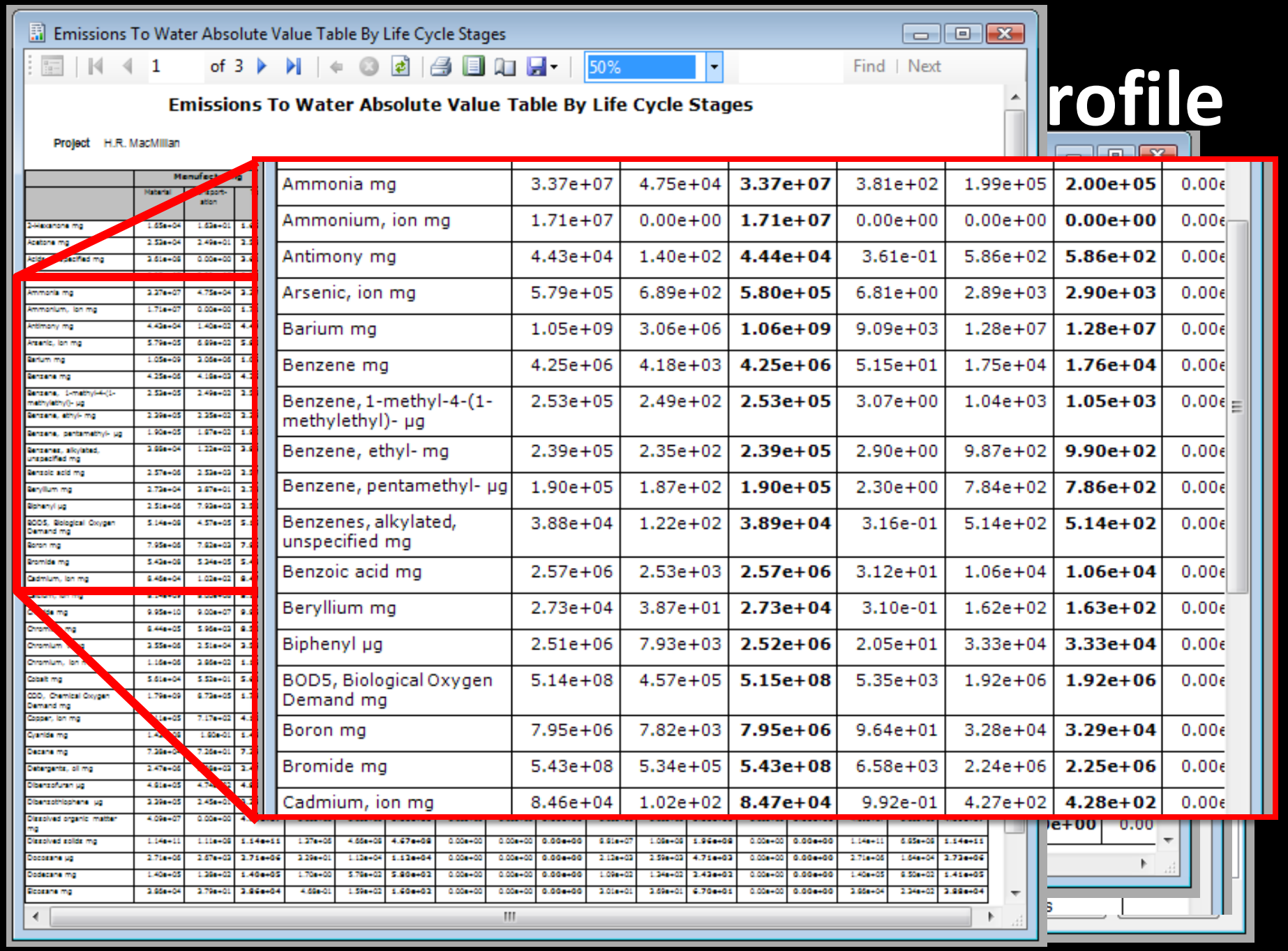
mns


Emissions To Water Absolute Value Table By Life Cycle Stages
1 of 3
50%
Find | Next
Emissions To Water Absolute Value Table By Life Cycle Stages
Project H.R. MacMillan
Ammonia mg 3.37e+07 4.75e+04 3.37e+07 3.81e+02 1.99e+05 2.00e+05 0.00e
Ammonium, ion mg 1.71e+07 0.00e+00 1.71e+07 0.00e+00 0.00e+00 0.00e+00 0.00e
Antimony mg 4.43e+04 1.40e+02 4.44e+04 3.61e-01 5.86e+02 5.86e+02 0.00e
Arsenic, ion mg 5.79e+05 6.89e+02 5.80e+05 6.81e+00 2.89e+03 2.90e+03 0.00e
Barium mg 1.05e+09 3.06e+06 1.06e+09 9.09e+03 1.28e+07 1.28e+07 0.00e
Benzene mg 4.25e+06 4.18e+03 4.25e+06 5.15e+01 1.75e+04 1.76e+04 0.00e
Benzene, 1-methyl-4-(1-methylethyl)- µg 2.53e+05 2.49e+02 2.53e+05 3.07e+00 1.04e+03 1.05e+03 0.00e
Benzene, ethyl- mg 2.39e+05 2.35e+02 2.39e+05 2.90e+00 9.87e+02 9.90e+02 0.00e
Benzene, pentamethyl- µg 1.90e+05 1.87e+02 1.90e+05 2.30e+00 7.84e+02 7.86e+02 0.00e
Benzenes, alkylated, unspecified mg 3.88e+04 1.22e+02 3.89e+04 3.16e-01 5.14e+02 5.14e+02 0.00e
Benzoic acid mg 2.57e+06 2.53e+03 2.57e+06 3.12e+01 1.06e+04 1.06e+04 0.00e
Beryllium mg 2.73e+04 3.87e+01 2.73e+04 3.10e-01 1.62e+02 1.63e+02 0.00e
Biphenyl µg 2.51e+06 7.93e+03 2.52e+06 2.05e+01 3.33e+04 3.33e+04 0.00e
BOD5, Biological Oxygen Demand mg 5.14e+08 4.57e+05 5.15e+08 5.35e+03 1.92e+06 1.92e+06 0.00e
Boron mg 7.95e+06 7.82e+03 7.95e+06 9.64e+01 3.28e+04 3.29e+04 0.00e
Bromide mg 5.43e+08 5.34e+05 5.43e+08 6.58e+03 2.24e+06 2.25e+06 0.00e
Cadmium, ion mg 8.46e+04 1.02e+02 8.47e+04 9.92e-01 4.27e+02 4.28e+02 0.00e

rofile

Summary Measure Table By Assembly Groups

1 of 1 100% Find | Next

Summary Measure Table By Assembly Groups

Project H.R. MacMillan

Material ID	Foundations	Walls	Beams and Columns	Roofs	Floors	Extra Basic Mater	**Total**
Primary Energy Consumption MJ	7.31e+06	3.54e+07	3.58e+06	3.48e+06	1.40e+07	4.05e+06	**6.78e+07**
Weighted Resource Use kg	1.13e+07	5.54e+06	2.74e+06	2.59e+06	1.34e+07	5.45e+05	**3.61e+07**
Global Warming Potential (kg CO2 eq / kg)	1.78e+06	4.61e+06	6.43e+05	5.35e+05	3.16e+06	4.73e+05	**1.12e+07**
Acidification Potential (moles of H+ eq / kg)	1.19e+06	3.05e+06	4.05e+05	3.41e+05	2.06e+06	3.26e+05	**7.37e+06**
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	8.86e+05	2.28e+06	3.19e+05	2.66e+05	1.57e+06	2.32e+05	**5.56e+06**
Eutrophication Potential (kg N eq / kg)	3.20e+04	1.54e+05	1.48e+04	1.30e+04	5.95e+04	1.28e+04	**2.86e+05**
Ozone Depletion Potential (kg CFC-11 eq / kg)	8.84e+05	2.28e+06	3.19e+05	2.65e+05	1.57e+06	2.31e+05	**5.54e+06**
Smog Potential (kg NOx eq / kg)	8.88e+05	2.28e+06	3.20e+05	2.67e+05	1.57e+06	2.32e+05	**5.56e+06**

Methods

- Outline
  - Learning Curve
  - Generic Assumptions
  - Challenges

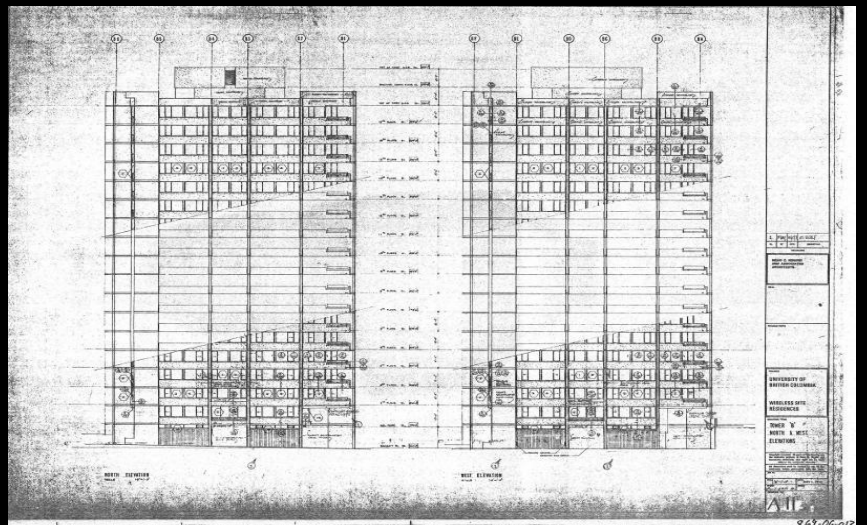
Learning Curve

- The project required a great deal of learning not only from the programs to be used, but the general concept of LCA itself

- Learning Curve for
  - Construction drawings
  - Onscreen Takeoff
  - Athena EIE
  - Data analysis for EIE (sensitivity analysis, building performance model)
  - Formatting inputs for Takeoffs and EIE

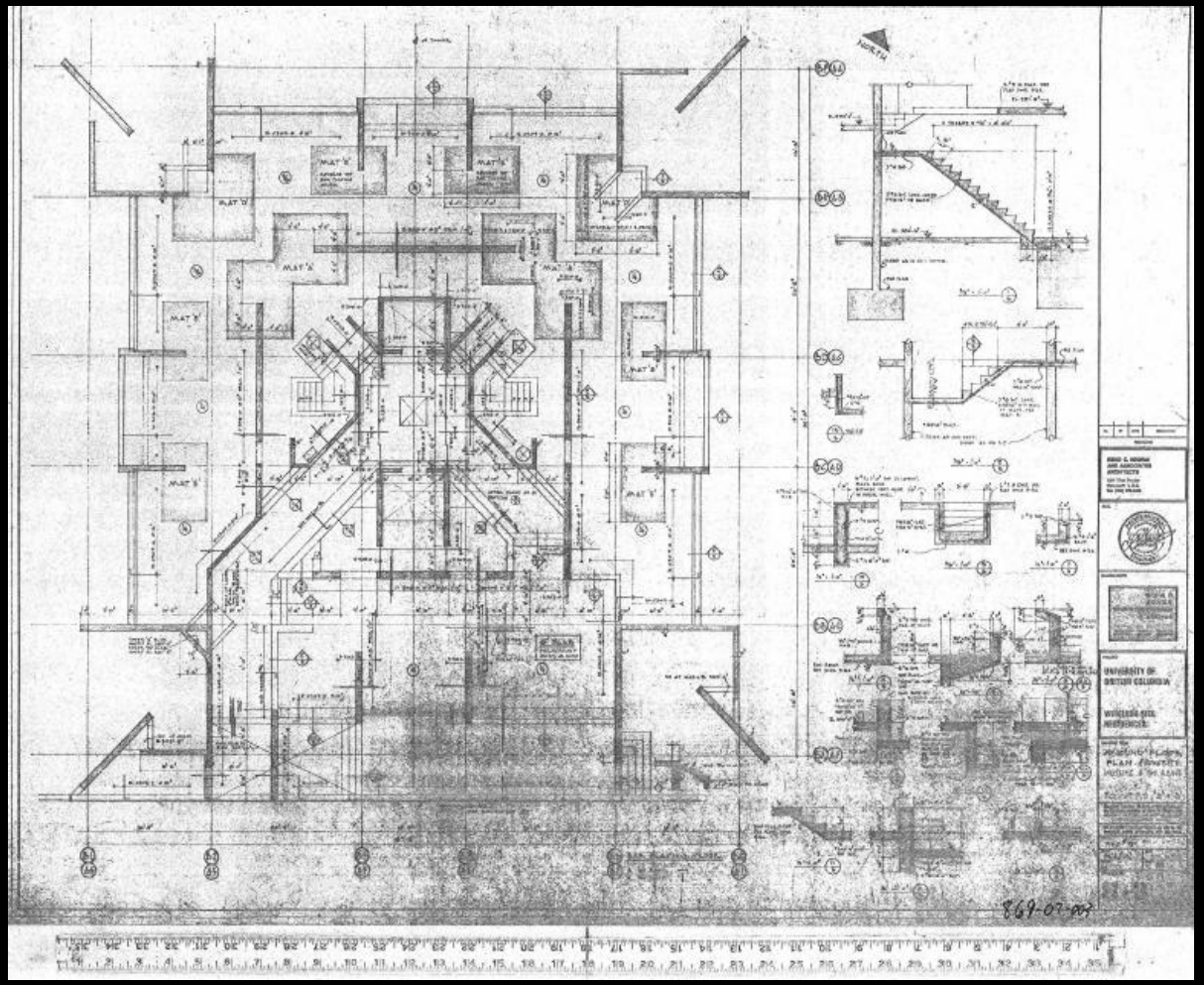
Generic Assumptions

- Use of typical floors to represent repeated floors
- Personalized modelling of complex conditions
- Assuming missing material details
  - Insulation, concrete, steel details/specifications



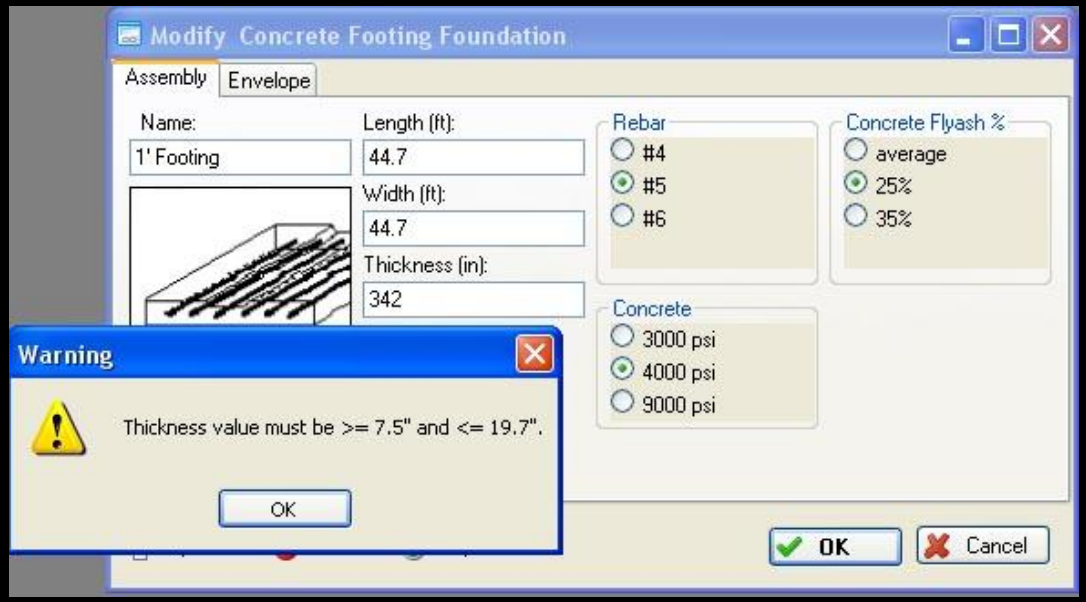
Construction Drawings Challenges

- Missing drawings
- Blurry drawings



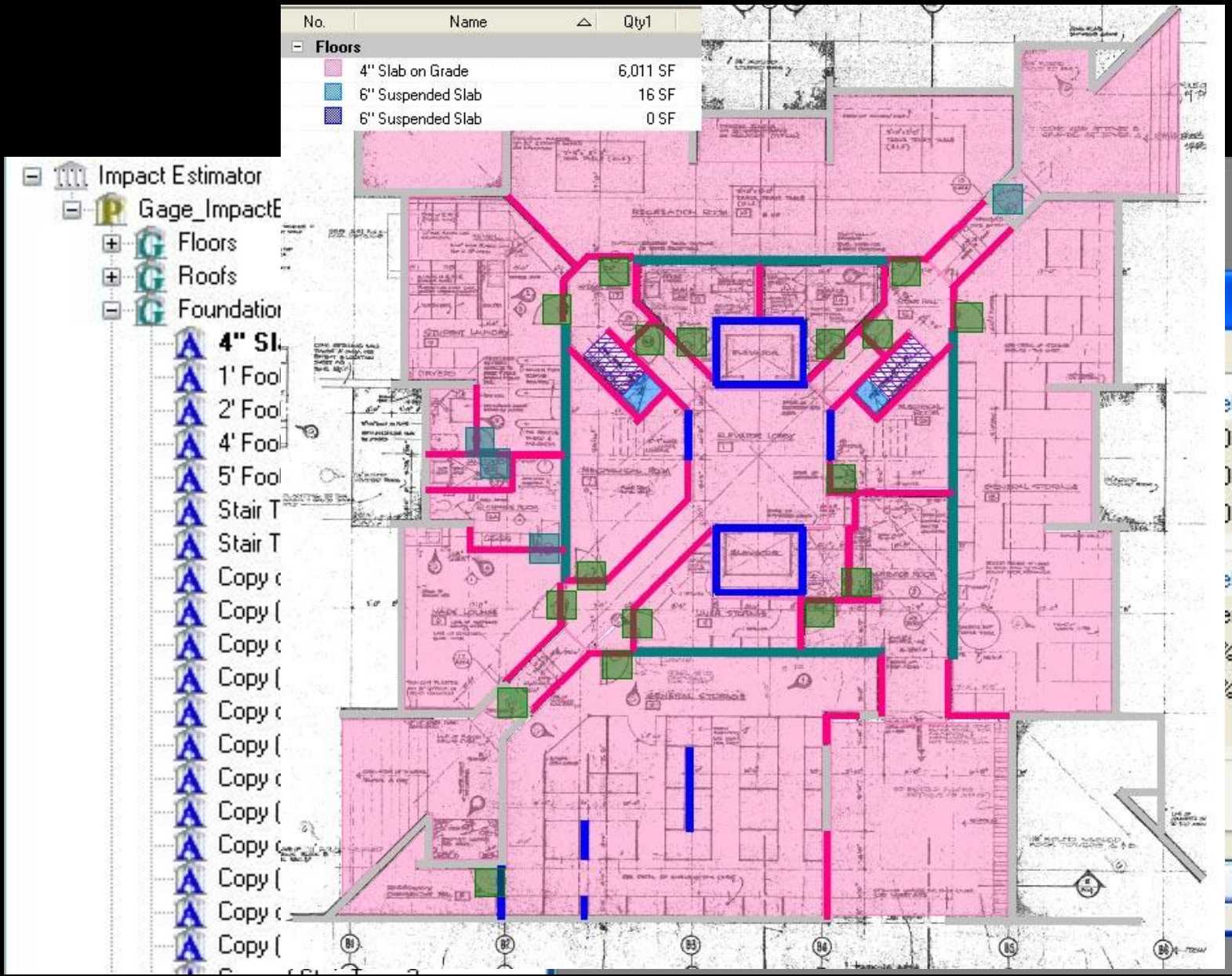
Athena EIE Challenges

- General Challenges
  - Beam and Column Modelling
  - Material Database (concrete strength, wall thickness selection)
  - Complex structure modelling (stairs, unique truss column structures)
- Version Challenges
  - Limit of 100 window per wall assembly for Athena software
  - General boundary limits for certain inputs
    - Span limits (No error for going over limit)
    - Footing thickness (7.5”-19.7”)



Formatting Challenges

- Nomenclature for takeoffs and EIE inputs
  - Nomenclature should be easy to understand
  - Should be the consistent for both programs for transparency
  - Allows anyone to carry the project into further detail with ease


No.
Name
Qty1
Floors
4" Slab on Grade
6,011 SF
6" Suspended Slab
16 SF
6" Suspended Slab
0 SF
Impact Estimator
Gage_ImpactE
Floors
Roofs
Foundatior
4" Sl
1' Fool
2' Fool
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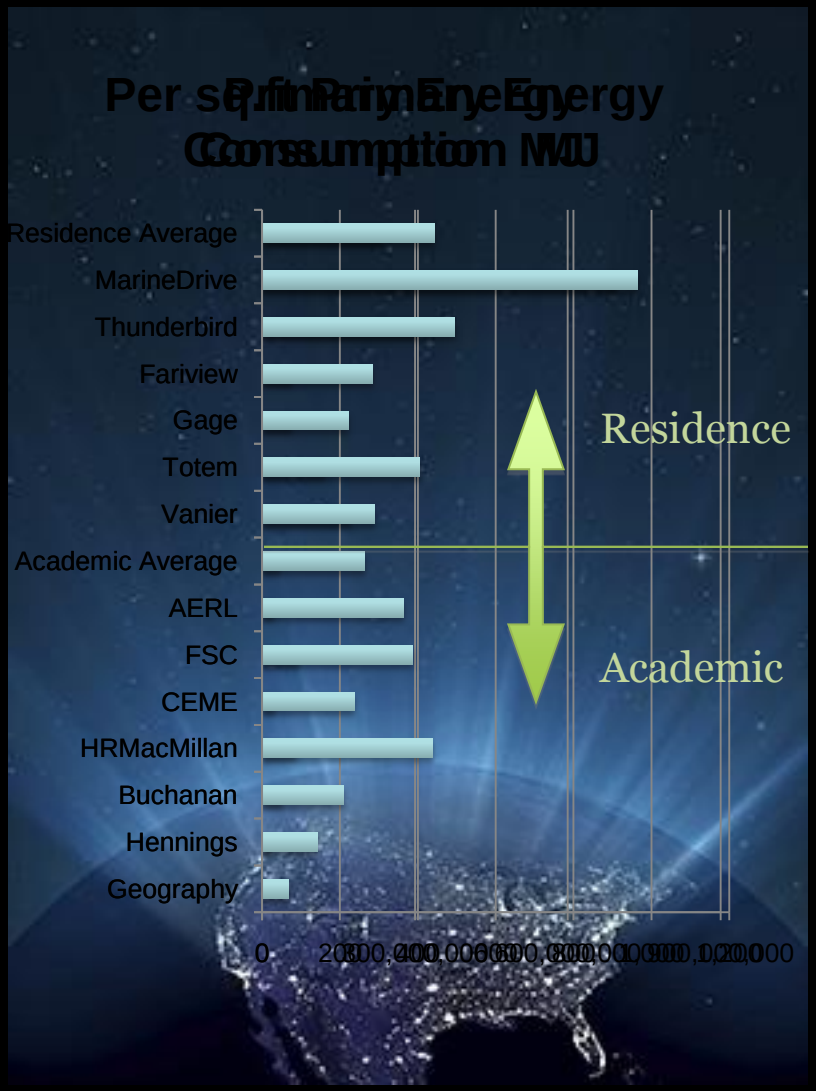
Methodology in Summary

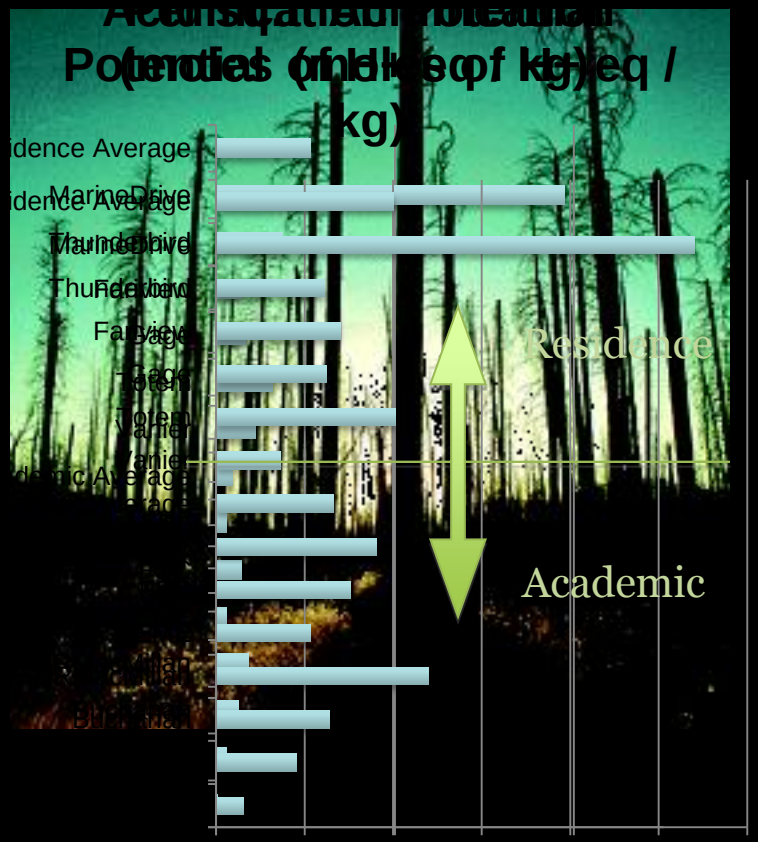
- Tasked with large project upfront that requires some planning but ultimately mistakes are inevitable
- A cyclic approach, where mistakes, inappropriate errors/assumptions are made and gone back to be fixed

Primary Energy Consumption

- All forms of energy, direct and indirect, that used to process the raw materials into the building product and transport it.
- Measured in mega-joules (MJ)



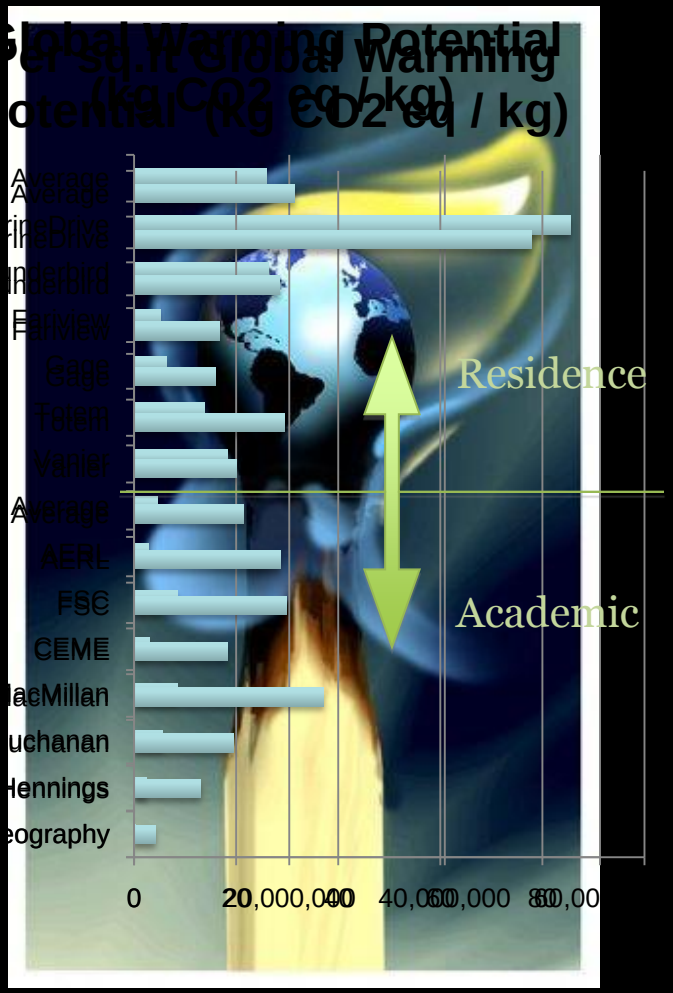
Acidification Potential



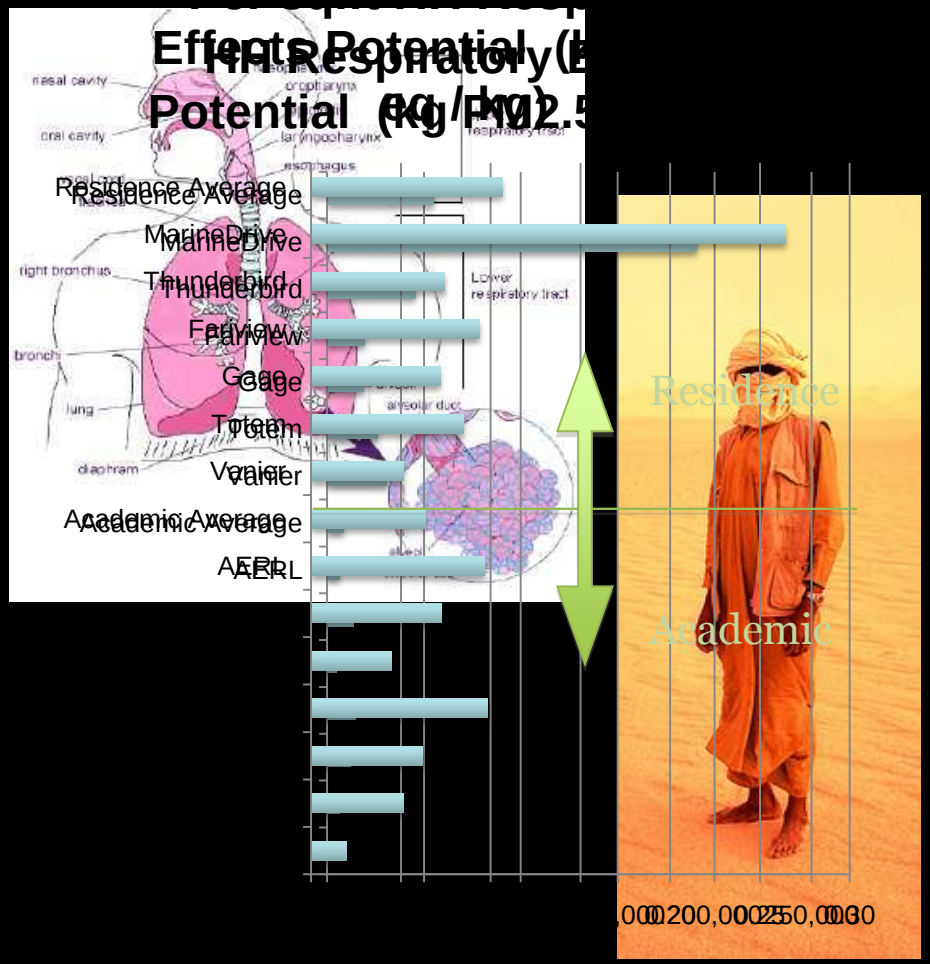
- Acidification is a predominately regional impact that can affect human health when NO_X or SO_2 reach high concentrations
- Expressed as a hydrogen ion equivalency based on mass balance calculations

Global Warming Potential

- The CO_2 equivalence for other greenhouse gases is a ratio of the heat trapping potential to CO_2, affected by a time horizon as different compounds have different reactivity in the atmosphere.
- Expressed in terms of CO_2 equivalence by weight



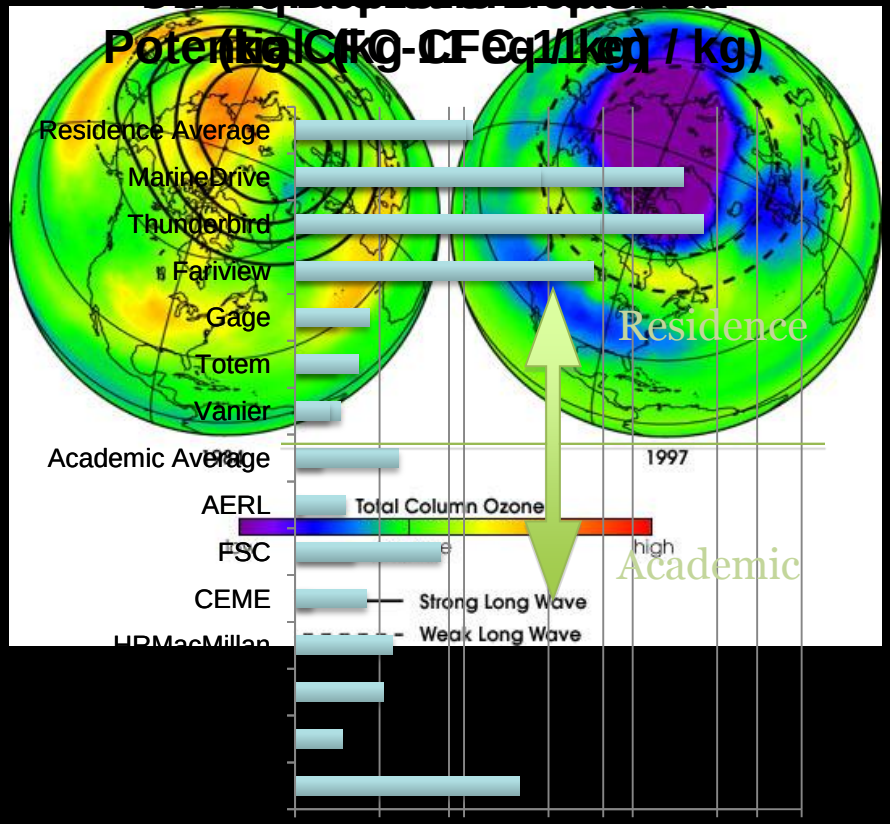
Human Health Respiratory Effect Potential



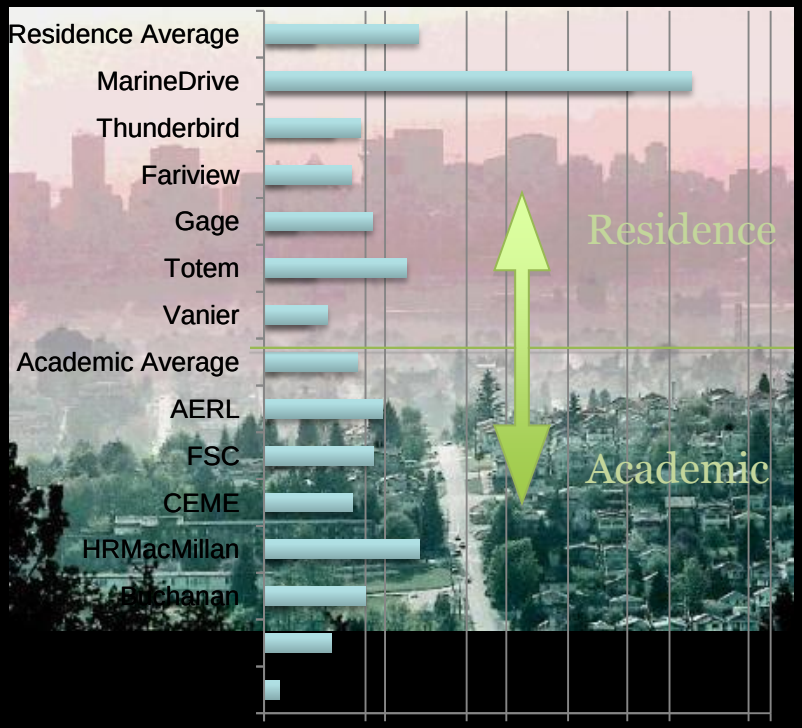
- Particulates can have a dramatic affect on human health due to respiratory problems
- The Impact Estimator uses TRACI's "Human Health Particulates from Mobile Sources" characterization factor to account for the mobility of particles of different sizes, thus equivocated them to a single size: $PM_{2.5}$

Ozone Depletion Potential

- The ozone layer absorbs most UV radiation
- Expressed in mass equivalence of CFC-11, based on their relative capacity to damage ozone in the stratosphere



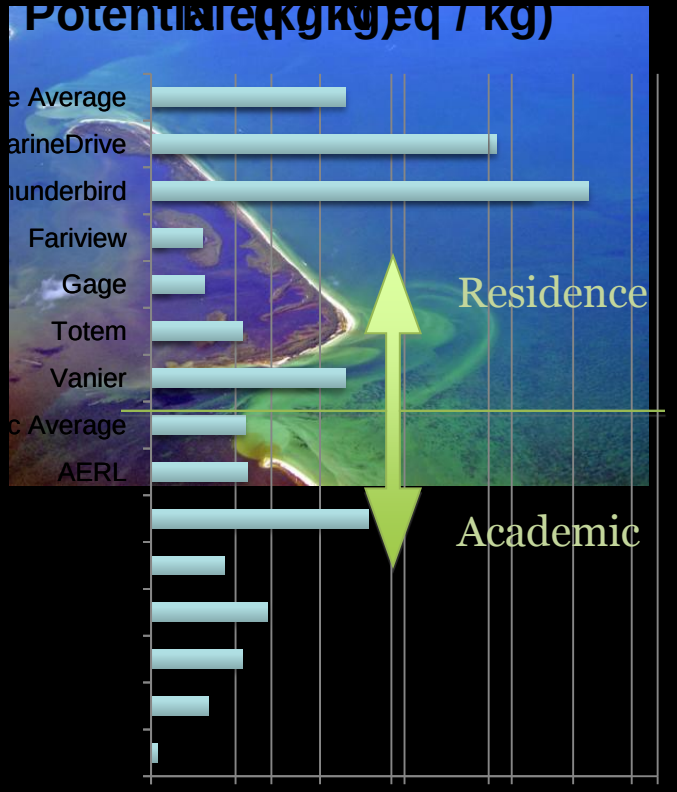
Photochemical Ozone Creation Potential (Smog)



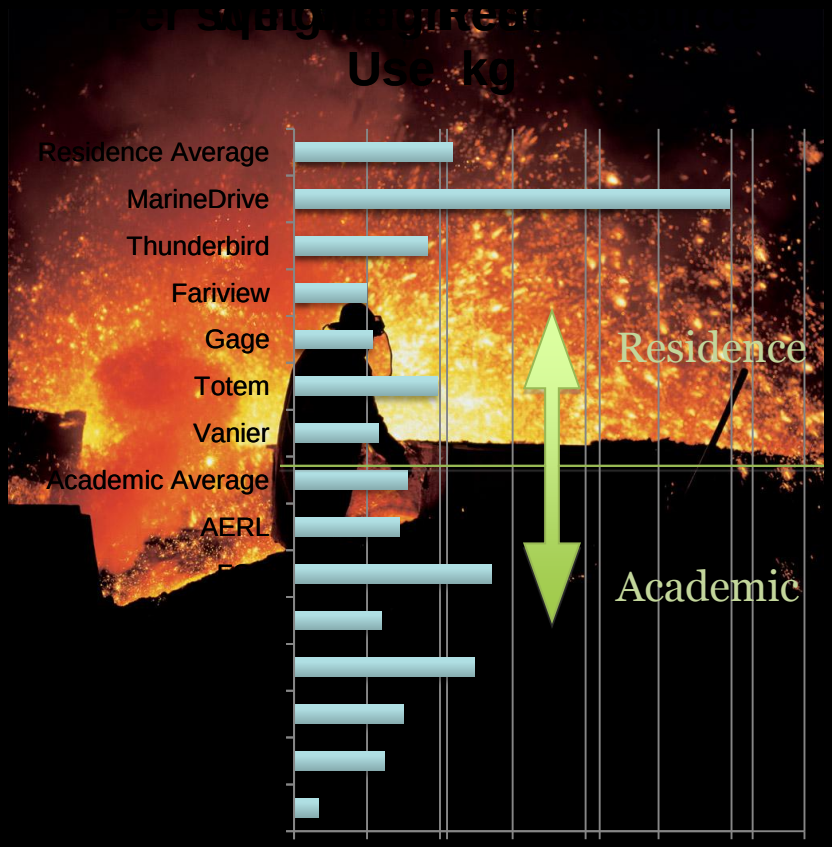
- Under certain climate conditions when air emissions are trapped at ground level and are exposed to sunlight as a result of the interaction of volatile organic chemicals (VOCs) and nitrogen oxides
- Expressed in terms of mass of nitrogen oxide equivalence

Eutrophication Potential

- Proliferation of photosynthetic plant life potentially choking out other aquatic life and/or producing other effects such as foul orders.
- Expressed in terms of mass equivalence of nitrogen



Weighted Resource Use



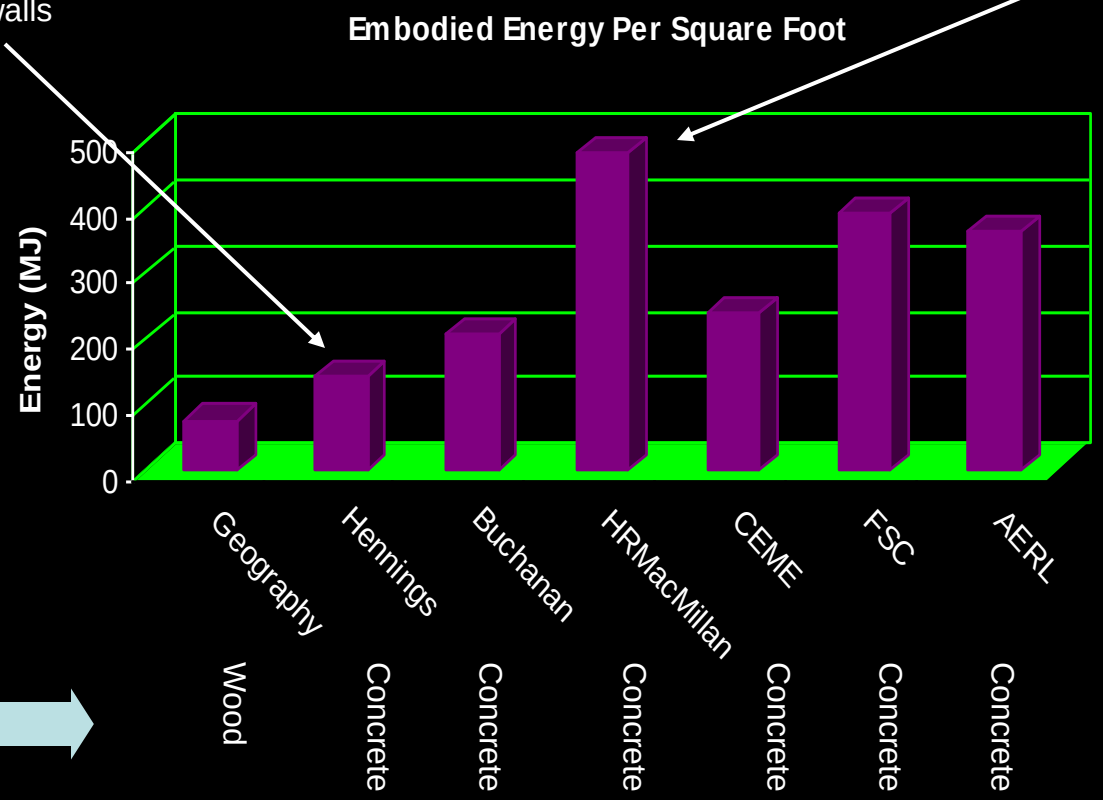
- An indication of the natural resources harvested from the earth to make materials like steel and concrete
- Expressed in what can be thought of as "ecologically weighted kilograms" that represent relative levels of environmental impact based on expert opinion.

Results – Influencing Factors

Academic Buildings

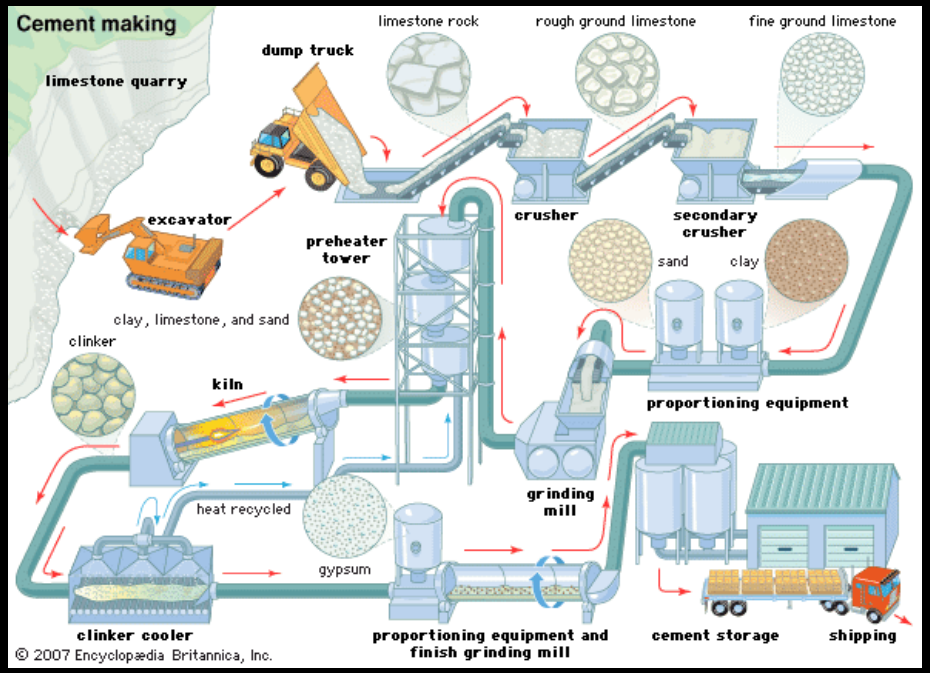
Concrete partition walls

Wood partition walls



Why the summary measure difference between concrete and wood?

One step of the concrete production process before batching



http://media-2.web.britannica.com

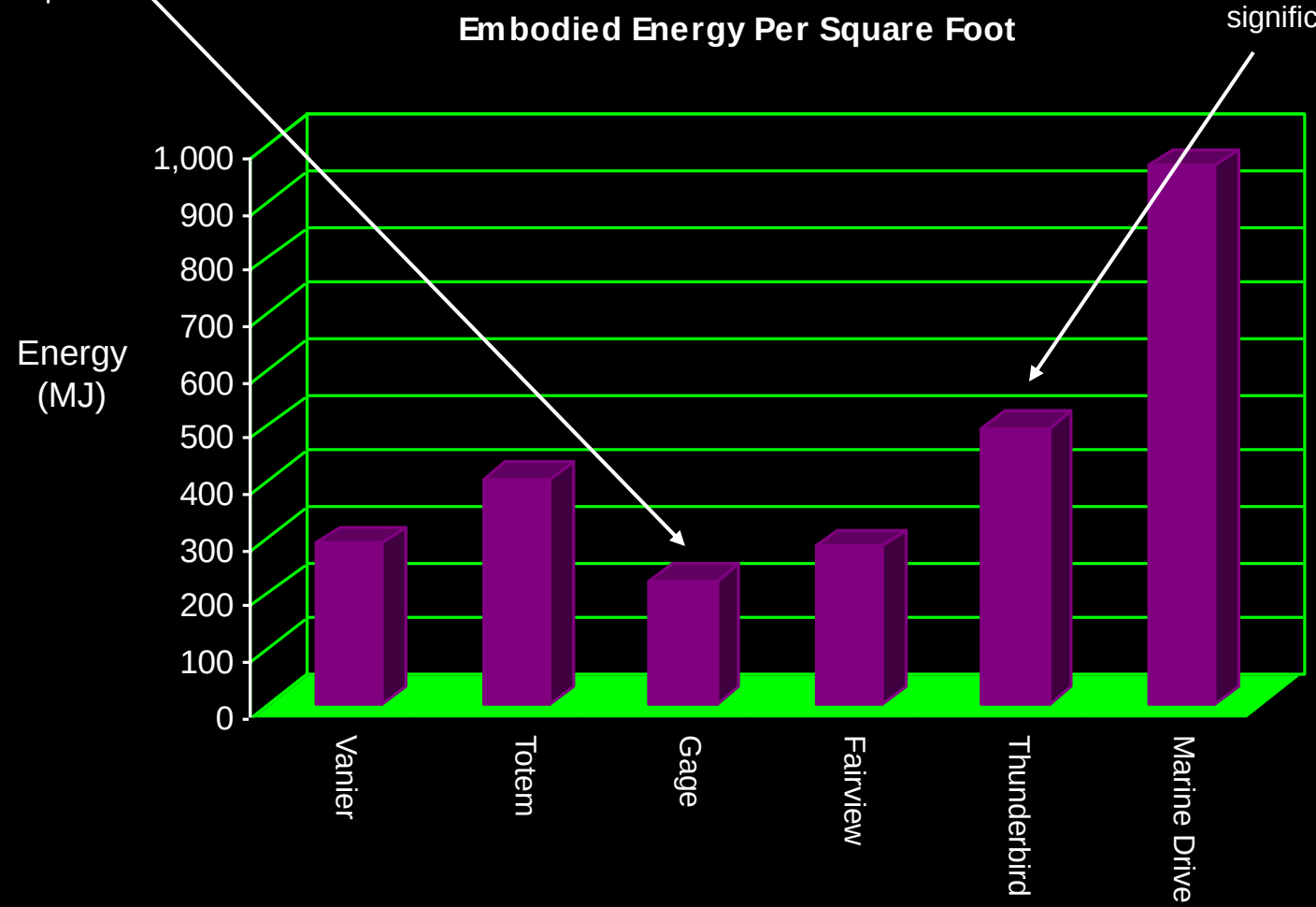
Dimensional lumber process

⟶ Harvest trees → Sawmill ⟶ Planer mill ⟶ Kiln drying ⟶ Shipping

Influencing Factors
Residence Buildings

High-rise construction difficult to compare

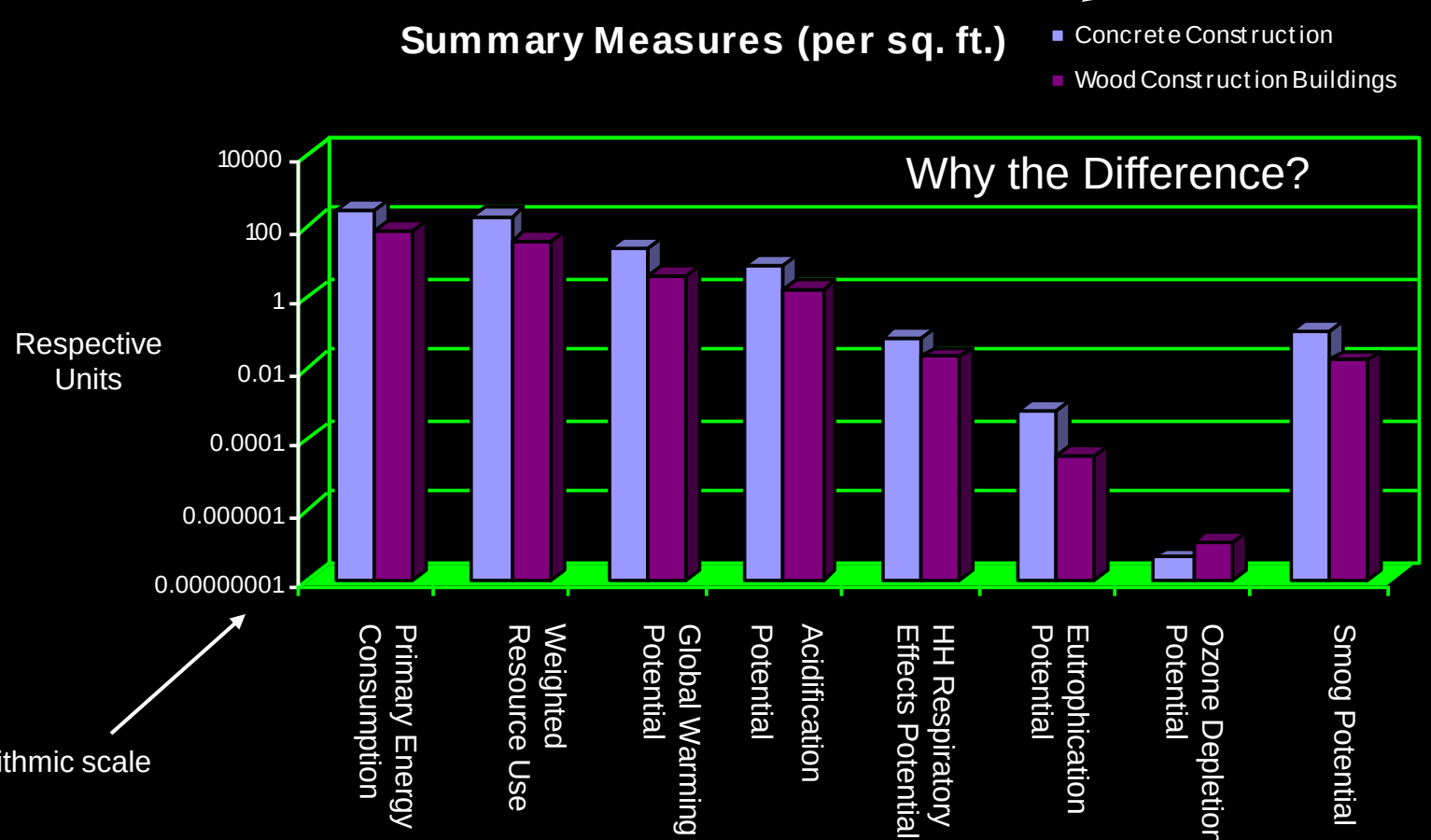
Sensitivity analysis reveals concrete more significant than wood



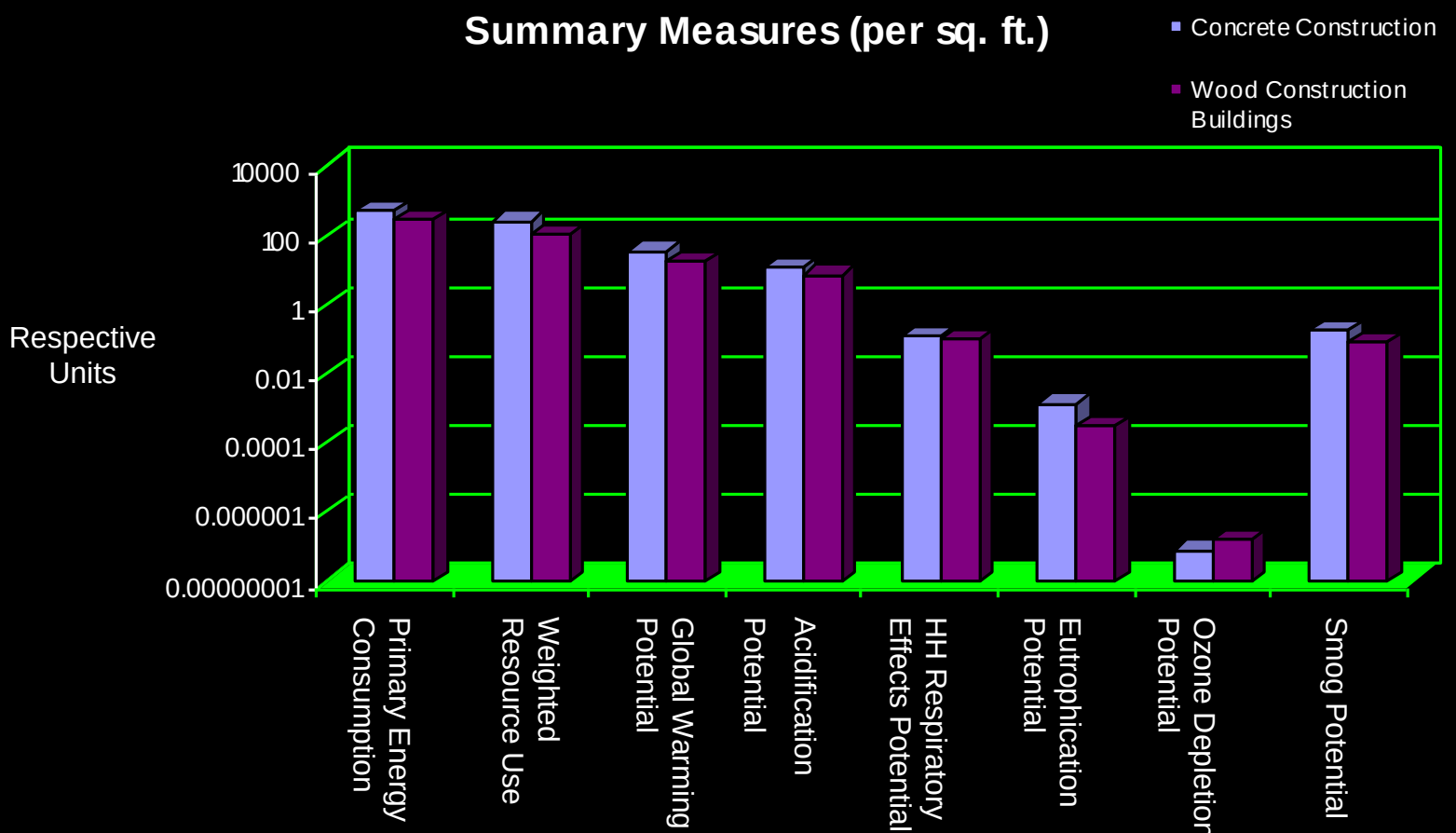
	Vanier	Totem	Gage	Fairview	Thunderbird	Marine Drive
Primary Construction Type	Concrete	Concrete	Concrete	Wood	Concrete & Wood	Concrete

Wood Vs. Concrete - Academic

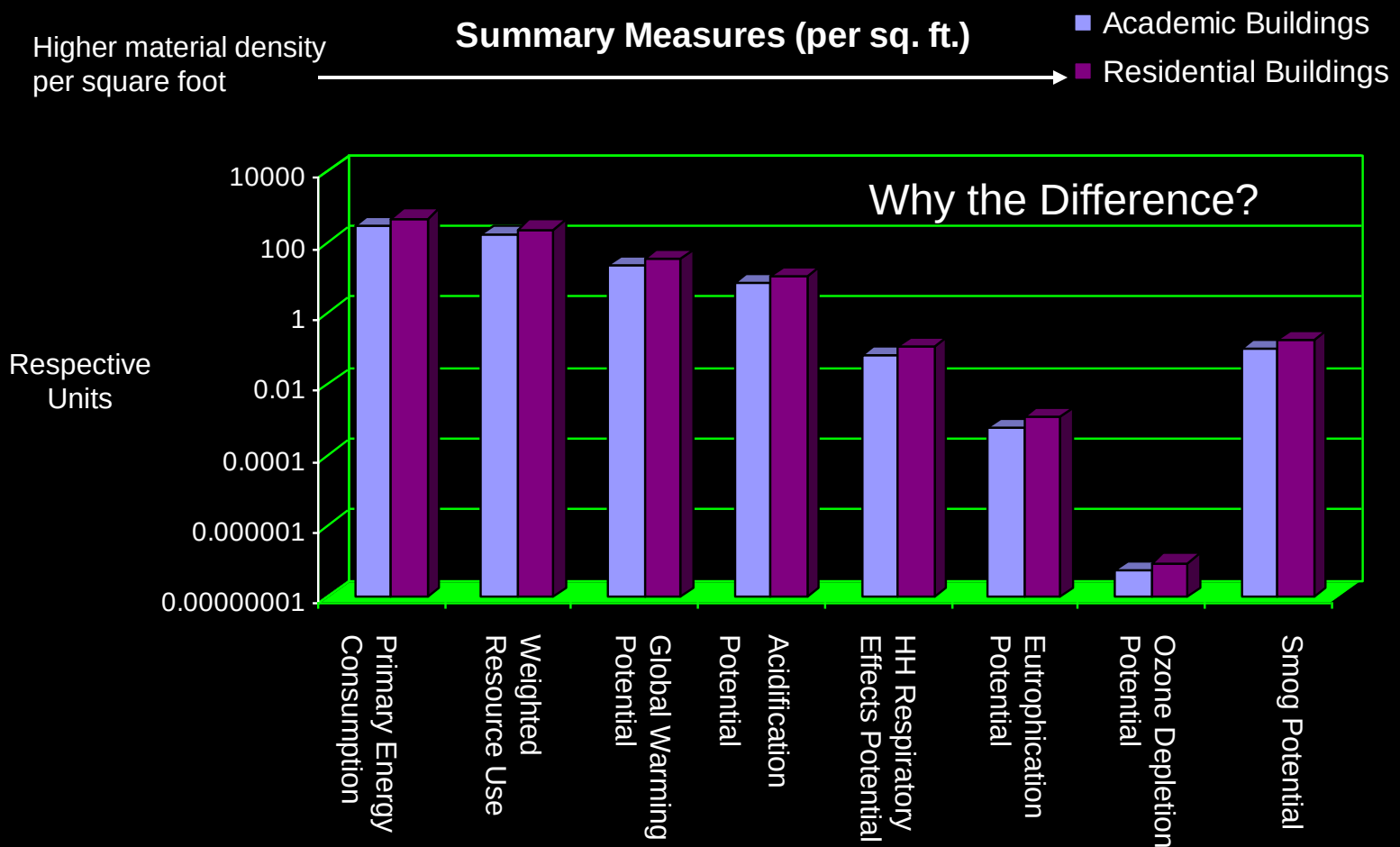
More input intensive manufacturing processes = greater emission amounts



Wood vs. Concrete - Residential



Residential Vs. Academic Buildings



How would these results appear using a different unit of measurement?

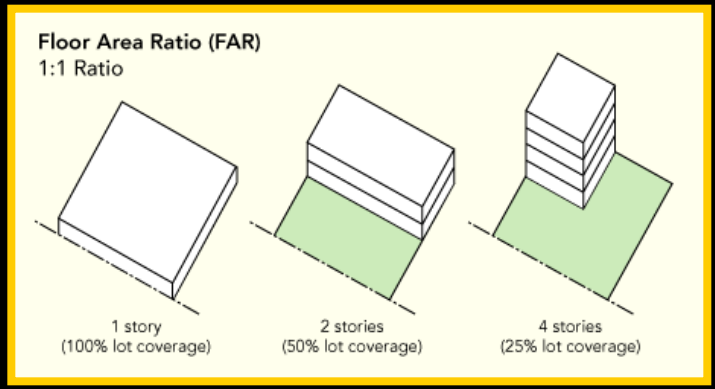
Laurent – Functional Units

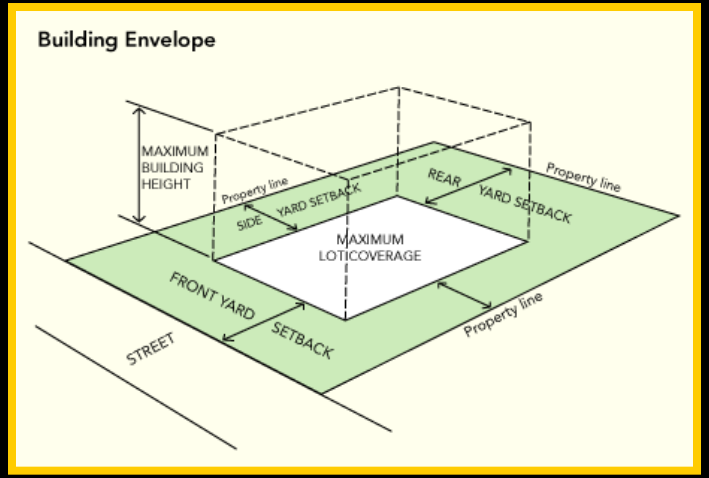
Functional Units

Impacts / ft^2 Academic & Impacts / ft^2 Residence

- How well does it account for different constructions types?
- Is a multi storey building equivalent to a one storey building with an equivalent area?
- Can their be additional ways to compare our results to improve our understanding of the impacts

Floors Occupancy Productive Use

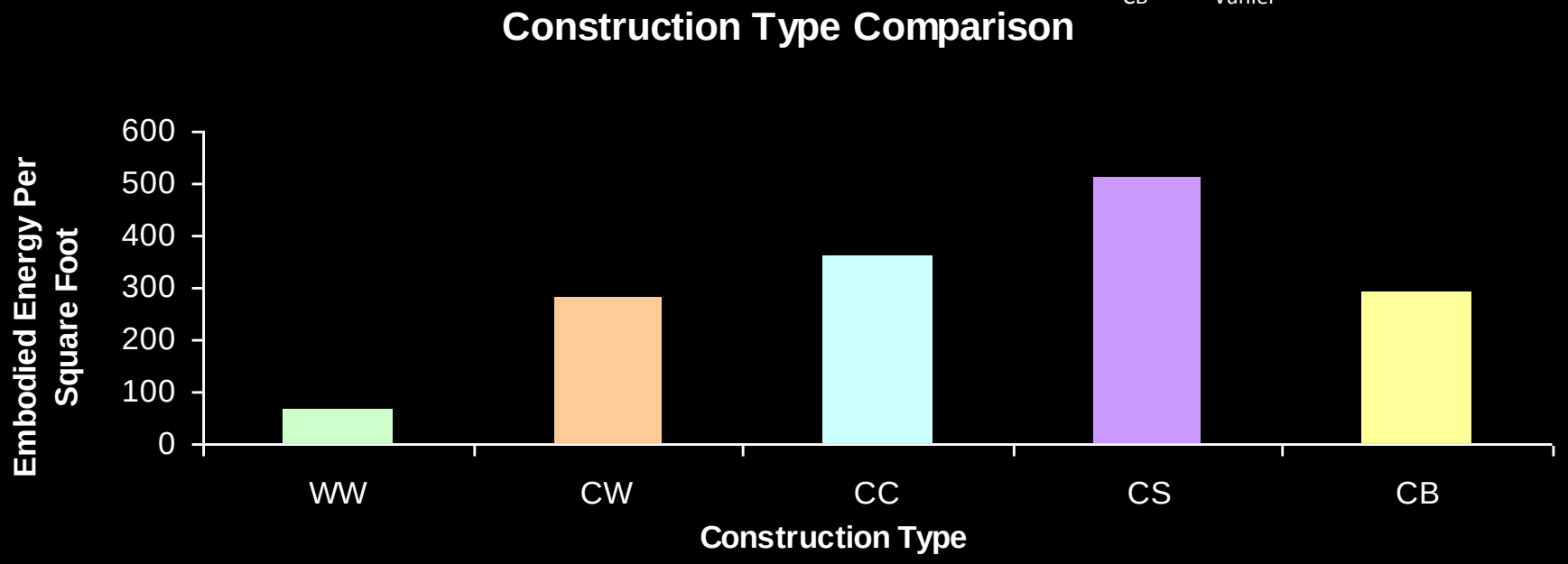




Embodied Energy/ Floor Area

- Academic and Residence
- Construction type
  - Structure
  - Interior Wall

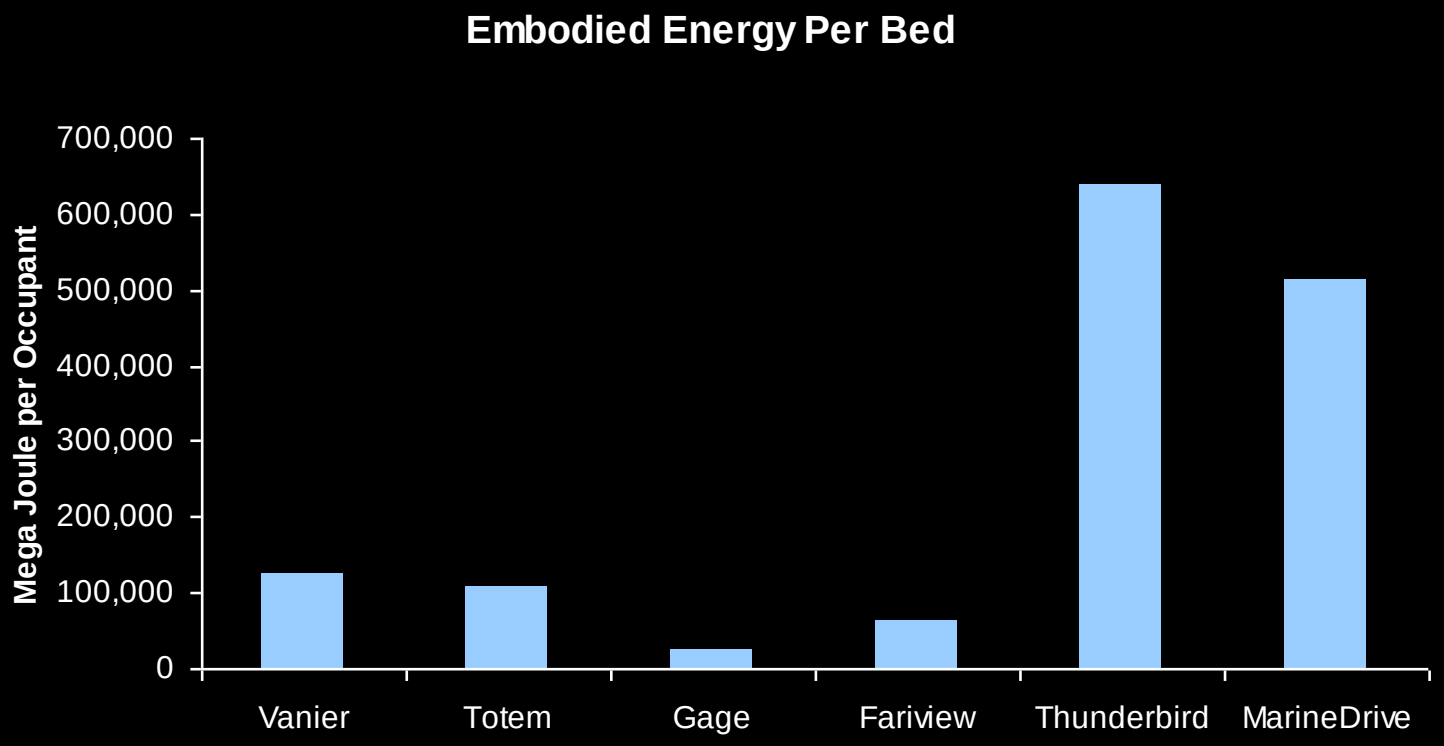
Buildings	
WW	Geography
CW	Hennings, Buchanan, Fairview, Thunderbird
CC	HR-MacMilan, CEME, Totem
CS	FSC, AERL, Gage, Marine Drive
CB	Vanier



Embodied Energy / # Beds

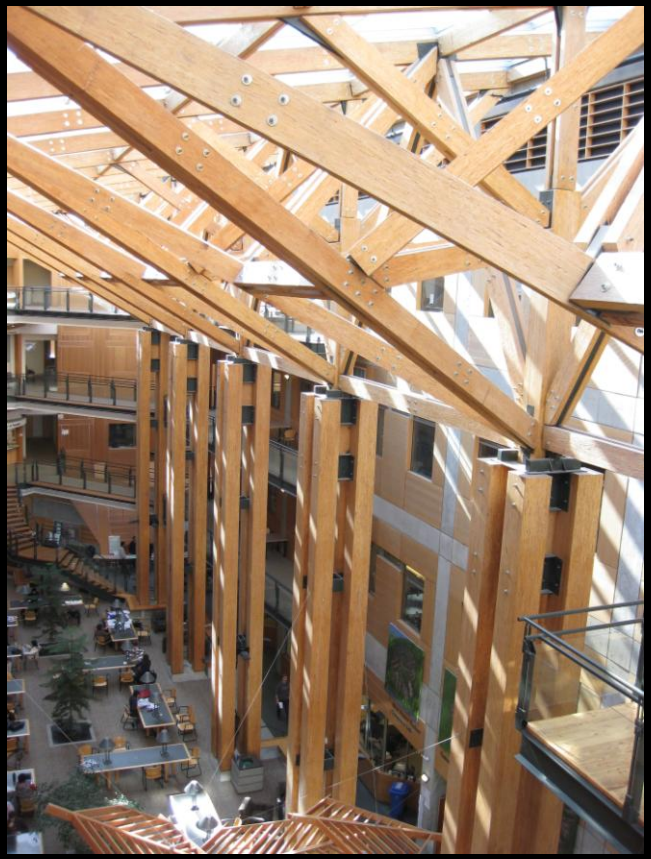
- Determines how well the building is being used
  - A building with labs may be better categories as embodied energy / room
  - A building with lots of class rooms or rooms maybe be better categories as embodied energy / occupants

  Provides a reference point for comparison

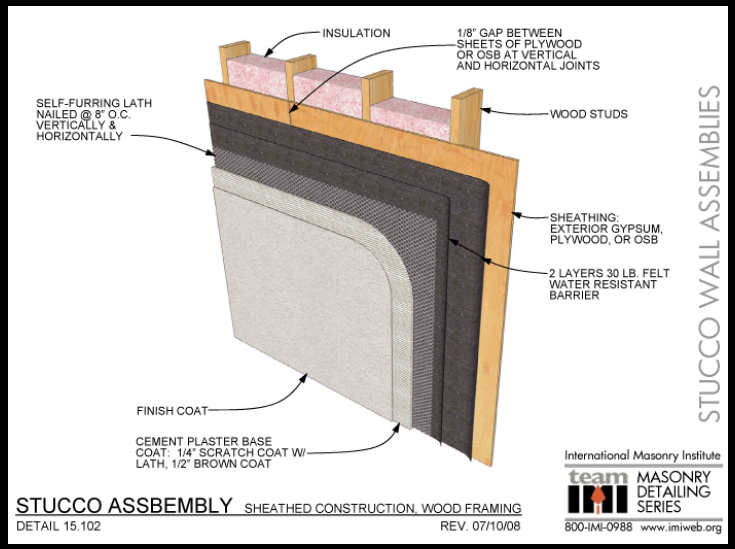


Embodied Energy / Productive Space

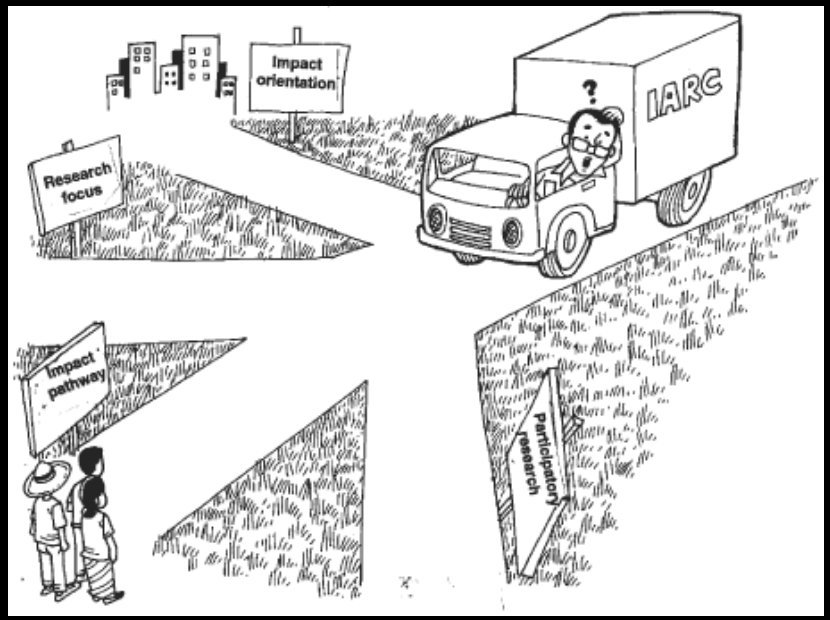
- How efficiently are the material being used by the functions they serve?
  - Study area
  - Lecture Halls
  - Walkways/hallways



< Forest Science Centre>



Functional Unit

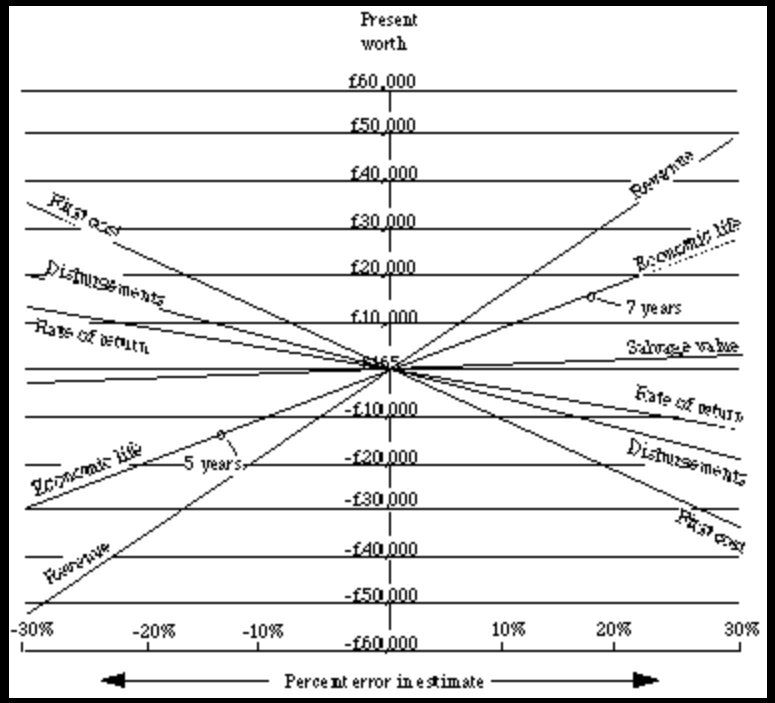


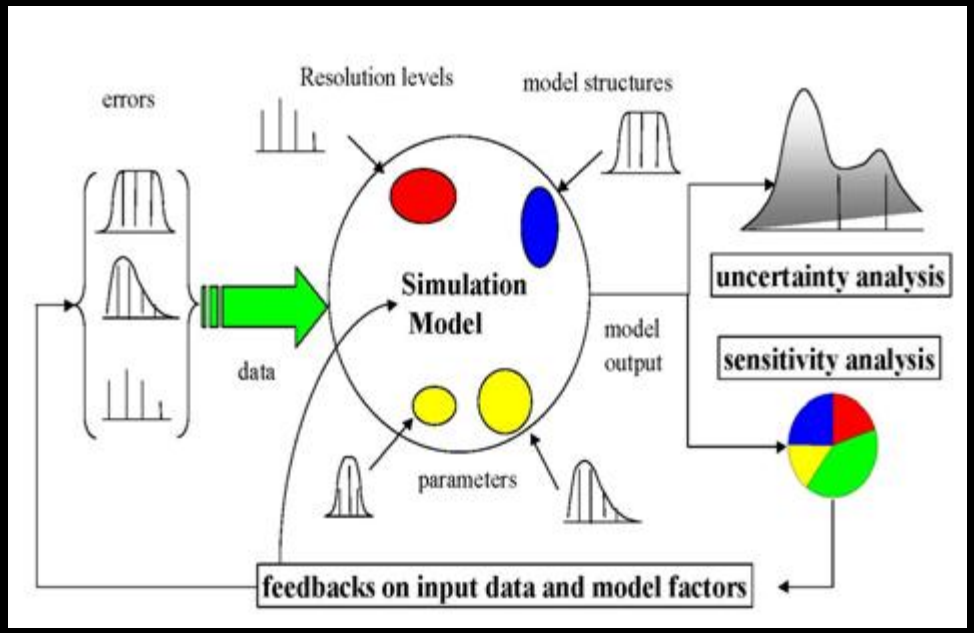
Sensitivity Analysis

- What is it?
- Process used in CIVL 498C Sensitivity Analysis
- Results
- Importance for future design and renovation

What is Sensitivity Analysis?

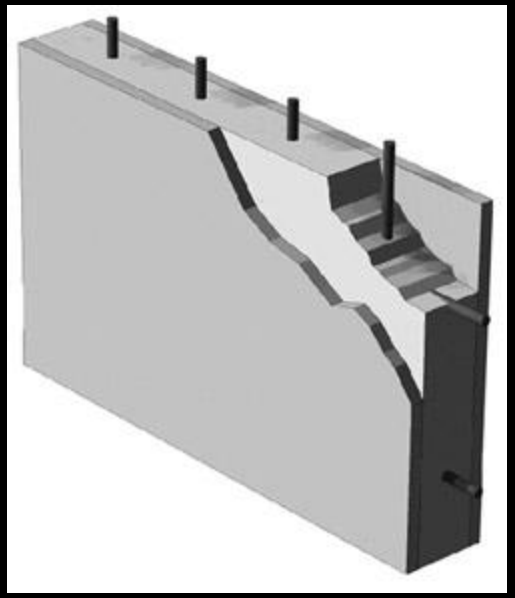
- Evaluation of materials or processes to determine influence of specific components on overall system





Process used in our Analysis

- 5 most prevalent materials
- 10% variation in quantity



Results

Summary Measures By Life Cycle Stage - No Change in Material Quantities

	Manufacturing			Construction		
	Material	Transport-ation	**Total**	Material	Transport-ation	**Total**
Primary Energy Consumption MJ	5.3E+07	1507857	**5.4E+07**	841825	3294917	**4E+06**
Weighted Resource Use kg	2.1E+07	48955.7	**2.1E+07**	38524	74985.1	**113509**
Global Warming Potential (kg CO2 eq / kg)	3409614	2662.75	**3412277**	62086.4	5801.46	**67888**
Acidification Potential (moles of H+ eq / kg)	1421923	901.876	**1422825**	32461.8	1856.91	**34319**
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	19343.3	1.08704	**19344.4**	35.0666	2.23299	**37.3**
Eutrophication Potential (kg N eq / kg)	62.2944	0.0065	**62.3009**	0.00193	0.01413	**0.0161**
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.03193	1.1E-07	**0.03193**	5.9E-10	2.4E-07	**2E-07**
Smog Potential (kg NOx eq / kg)	16745.3	20.3161	**16765.6**	998.071	41.5088	**1039.6**

Summary Measures By Life Cycle Stage - +10% Gypsum Board

	Manufacturing				Construction			
	Material	Transport-ation	**Total**	**% Change Manufacturing**	Material	Transport-ation	**Total**	**% Change Construction**
Primary Energy Consumption MJ	5.9E+07	1911361.3	**6E+07**	**12.77**	841825	3500678	**4E+06**	**4.97**
Weighted Resource Use kg	2.3E+07	65478.22	**2E+07**	**12.49**	38524	79667.6	**118192**	**4.12**
Global Warming Potential (kg CO2 eq / kg)	3824907	3367.08	**4E+06**	**12.19**	62086.4	6198.13	**68284**	**0.58**
Acidification Potential (moles of H+ eq / kg)	1571182	1150.66	**2E+06**	**10.50**	32461.8	1982.01	**34444**	**0.36**
HH Respiratory Effects Potential (kg PM2.5 eq / kg)	20631.7	1.38731	**20633**	**6.66**	35.0666	2.38334	**37.45**	**0.40**
Eutrophication Potential (kg N eq / kg)	63.0846	0.00868	**63.093**	**1.27**	0.00193	0.01509	**0.017**	**6.01**
Ozone Depletion Potential (kg CFC-11 eq / kg)	0.0321	1.3874E-07	**0.0321**	**0.53**	5.9E-10	2.5E-07	**3E-07**	**6.81**
Smog Potential (kg NOx eq / kg)	17442.9	25.951	**17469**	**4.19**	998.0	44.30	**1042.4**	**0.26**

Importance to future design and renovation

- Guides decisions in design and renovation phase
- Easily pinpoint materials/assemblies significantly impacting performance
- Quantitative/objective analysis
- Combine with other tools for deeper analysis

Energy Analysis

The energy model was defined as:

EMBODIED ENERGY + OPERATIONAL ENERGY

Energy Consumption Comparison

Analyzed Insulation Value of Exterior Components:

- Exterior Walls R-18
- Windows R-3.45
- Roof R-40

Upgrade Standard – UBC Residential Environmental Assessment Program (REAP) Guidelines

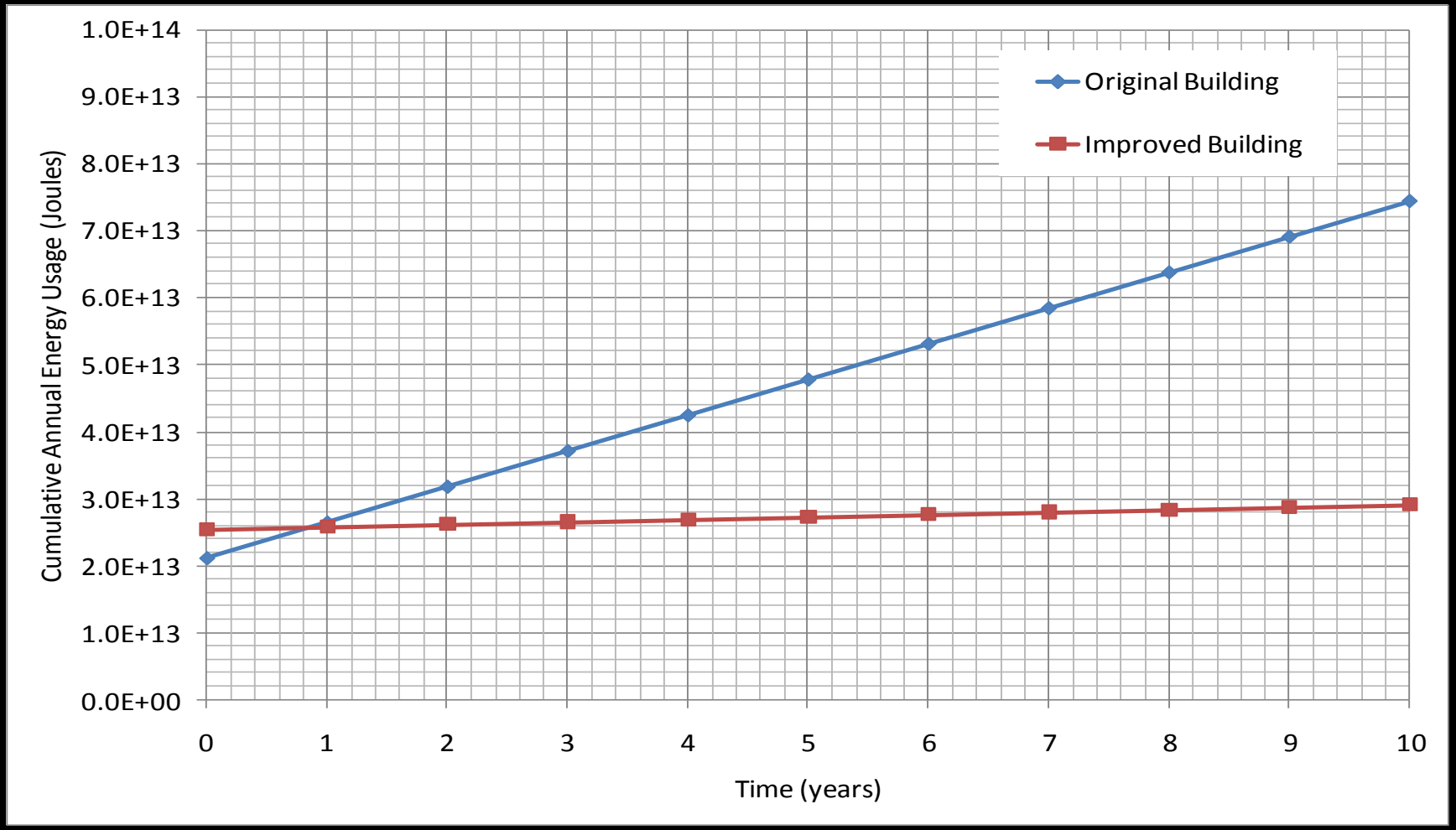
Not Taken into Account

- Economic Analysis

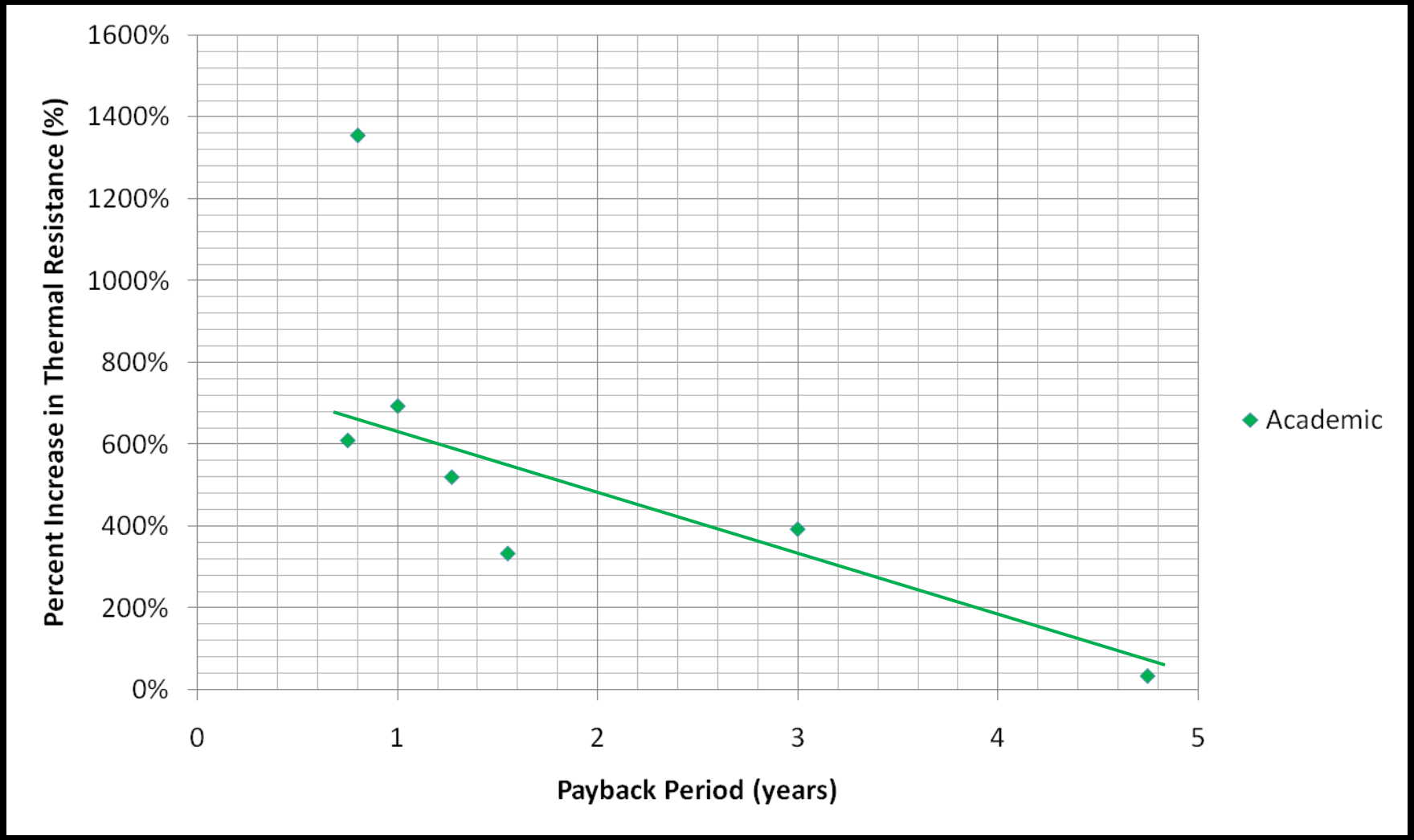
- Maintenance Cycles

- Feasibility of Installation

The Hennings Building Cumulative Energy Usage Vs Time



Percent Increase in R-Value vs. Payback Period



Further Analysis

- This is a sample of an expletory study of what can be done with LCA
- This study utilized the basics of embodied and operational energy analysis

Where Can We Go?

Manufacturing

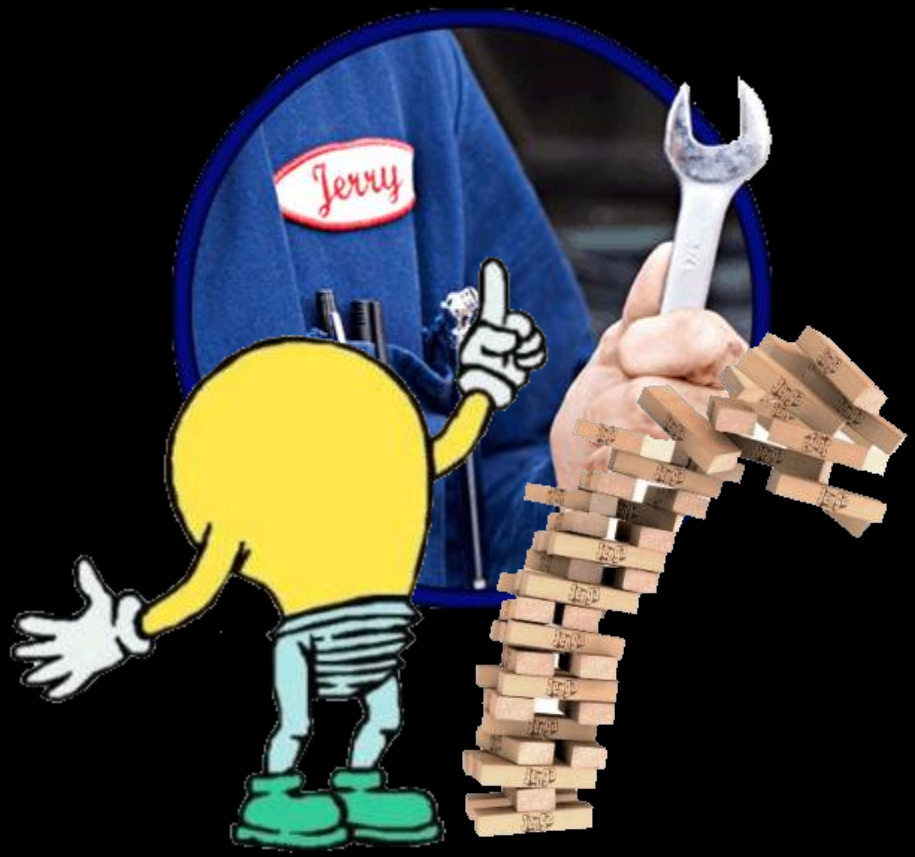
Basic Materials

Construction

Full Life Cycle

- Manufacturing
- Construction
- Maintenance
- Operating Energy
- End-of-Life

Basic Materials



Different Materials

Manufacturing	Basic Materials
Construction	Finishing Materials
Maintenance	Furniture
Operating Energy	Electronics
End-of-Life	Professors

Other Structures

Manufacturing	Basic Materials	Other Buildings
Construction	Finishing Materials	Roads
Maintenance	Furniture	Walkways
Operating Energy	Electronics	Monuments
End-of-Life	Professors	Turf Fields

Future Applications

Economic payback

- Money talks
- Private sector interest in LCA will depend on it
- Useful for renovations as well as new construction

Future Applications

Standards and Policies

- The development of standards and rating systems such as REAP, LEED, etc.
- LEED 2009 contains a section for LCA

Future Applications

Quantifying Green

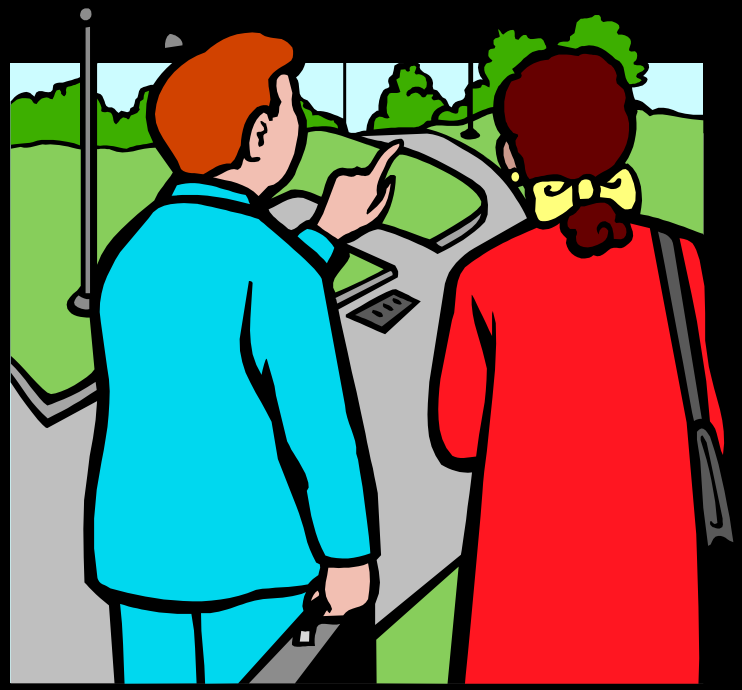
- LCA gives credibility to claims of being green
- Compare UBC with other universities
- Compare UBC with private sector buildings

Photo by Trevor Curtis

Future Applications

Holistic approach

- LCA is only part of the story
  - Functional land use efficiency (important in high population regions)
  - Site planning (green space, parking, storm water management etc.)



Future Applications

Enhance the study by including:

- Mechanical Engineering
- Electrical Engineering
- Architecture
- City planning
- Construction techniques
- Green materials and practices

Thank You!